NEW PRODUCT DEVELOPMENT: A STUDY OF THE ADOPTION, USAGE AND IMPACT OF TOOLS AMONG SMALL HIGH TECHNOLOGY FIRMS

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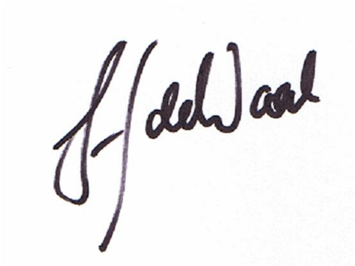
DECLARATION

I declare that the thesis hereby submitted is my own independent work and has not previously been submitted by me for a degree at another university.



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Abstract

This thesis reports on the associations between a variety of factors related to the adoption and use of 76 well-known new product development (NPD) tools on NPD performance at the project level in small high technology firms. The specific factors of interest are determinants of tool adoption, tool diffusion, thoroughness of use, flexibility of use, tool adaptation, user familiarity with tools, and tool satisfaction. An invitation-only online survey was administered to 99 organisations fitting the criteria of this study to determine patterns of tool adoption and use. A variety of inferential statistical techniques was used to analyse the data. The results show lesser tool adoption patterns in comparison with larger firms elsewhere, with the majority of tools not used to their full potential. It furthermore provides useful insights into usage and performance attributes of tools, individually and collectively. Of significance is that a greater uptake of tools may not necessarily lead to increased NPD performance; instead, it is the degree of thoroughness of implementation that shows a direct association with performance improvements.

The survey findings were followed up with in-depth case studies of five firms to investigate and explain observed phenomena, and assess the strengths and weaknesses of tool practices at the project level. The results show that practitioners' tool needs change during the life of a project and become more sophisticated as the firm matures. They also explain why some tools are thoroughly used, and others not.

The findings of this research have implications for both theory and practice. Theoretically, this study introduces different models and categories of tools and explains how their use can achieve a better overall understanding of tool application. Practically, the results provide managers and practitioners with several useful tool guides, benchmarking tables and models to aid in the selection and use of tools in NPD projects of any type.

Key Words: Innovation, new product development, process, tools, adoption, adaptation, performance

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1 INTRODUCTION

In this chapter, I present an overview of the thesis. The first section provides a background to the research to enable the framing of the research problem. Next, I provide a justification of the research, followed by an overview of the research methodology. In section four, I present the research questions that I derived from the literature review in Chapter 2. The fifth section specifies the assumptions, followed by two sections that state the delimitations and contributions of the research. The last section provides an overall summary of the contents of the thesis.

1.1 Background to the Research

The ability to create new products is a critical component in the success of any business. This is reflected in a recent survey (Jain, 2006) that shows for all industries that 22% of a typical company's sales come from new products, which is made up of line extensions (24%), product improvements (19%), market extensions (17%), and new-to-the-company and the world (12%). 'Others' account for the remaining 28%. For successful high technology firms the corresponding overall figure is more than double - being more than 50% (Balbontin, Yazdani, Cooper, & Souder, 2000).

While innovation is a primary source of wealth creation and absolutely essential for corporate survival (Dillon, Lee, & Matheson, 2005), worldwide firms still struggle to get it right. A 2005 survey by the Boston Consulting Group of more than 900 top executives found that even though companies continue to pour money into innovation, a majority of their senior executives are not happy with their returns on this investment (Venables, 2005). If it is true that innovation management is a learned capability as Tidd, et al. (2005) claim, it appears that managers are not sufficiently competent in this particular aspect of their jobs. Cooper and Kleinschmidt (1993) agreed with this sentiment almost two decades ago when stating that there is a clear gap between managers' perceptions of, and the reality of, criteria for successful innovation. Another study at almost the same time further supports this notion, having found that only 7% of managers were aware of the main findings of new product development (NPD) research, and only half of these had attempted to apply the results of the research (Barclay, 1992). It seems that very little has changed in recent times. NPD research (Cooper, Edgett, & Kleinschmidt, 2004a) found that more than 40% of NPD projects fail to meet objectives, a result that provides ample scope for improvement to those firms that find this situation unsatisfactory.

The innovation problem facing firms worldwide is twofold. The first relates to firms arguably not doing enough of it. Most consumer and industrial firms operate in markets characterised by advancements in technology, rapidly changing consumer demand, increased competition, shorter product life cycles, and increasing demand for higher quality product and performance (Jain, 2006; Koufteros, Vonderembse, & Jayaram, 2005; McIvor & Humphreys, 2004; Nijssen & Frambach, 2000). Consequently, firms are under constant pressure to innovate more frequently and launch products in quick succession.

The second innovation issue relates to how firms manage innovation – focusing not only on increasing output, but also on innovating more effectively and efficiently at the same time - and then to successfully commercialise such innovations. In terms of product innovation, the objective is to maximise NPD productivity, defined as output (measured as new product sales or profits) divided by input (measured as research and development (R&D) or NPD costs and time). Recent evidence suggests that NPD productivity is declining in the USA as new product sales dropped 4.6 percentage points between the mid-1990s and mid-2002, while R&D spending remained constant (Cooper & Edgett, 2008). Comparative figures lacking for other parts of the world, managers throughout the world face the never-ending quest for innovating more and doing it better.

1.2 Justification for the Research

Understanding factors such as NPD process, innovation supportive organisation, NPD tools, the firm's external environment, post-launch marketing effort, etc. that influence NPD has been of interest to researchers for many decades. While there is considerable consensus about how NPD should be managed, "there are many more areas where research into NPD management is lacking" (Ledwith & O'Dwyer, 2008, p. 99). One such area is the use of NPD tools in support of new product development projects within small firms. Ample evidence suggests that increasing the use or uptake of appropriate NPD tools during the NPD process and using these tools more effectively can improve NPD performance (Cooper & Edgett, 2008; Maylor, 2001; McQuater, Scurr, Dale, & Hillman, 1995; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995), for example, help minimise the substantial cost of failed NPD projects (Cooper, 1994; Song, Souder, & Dyer, 1997). To date there has been limited research dedicated to unraveling the factors and patterns in NPD tool application and use among firms that are small in world terms in terms of annual turnover and number of staff employed. Thia, Chai, Bauly, and Xin (2005) suggested that future tool research cover a wider selection of companies that include small private companies. Small firms are important as, in general, they account for significant employment, innovation and social and economic growth in both developed and developing countries. Small high technology firms, in particular, furthermore make a major contribution to industrial innovation and technological change, unlike less technology-oriented firms that only occasionally introduce fundamentally new products (Akgün, Lynn, & Byrne, 2004). Considering the importance of small high technology firms and the limited tool research among these firms, there is no doubting the importance of this domain of research. Hecker (1999) defined high technology firms as scientific, technical and engineering ones that demand in-depth knowledge of the theories and principles of sciences. High technology industries are defined as ones having "a great dependence on science and technology innovation that leads to new or improved products and services" (Cincinati USA, 2010, p. 1). Adopting these definitions, I conducted this study on NPD tools among New Zealand's high technology engineering/manufacturing firms that produce sellable units (excluding service firms). A particular characteristic of these firms is its relative small size in terms of both turnover and number of staff employed. Section 2.2.7 (p. 28) provides further rationale for studying the global small-firm phenomenon. Where corresponding data for larger firms exists, the research highlights the similarities and differences in practices and points out areas of weakness within small firms.

1.3 Overview of the Research Methodology

The research strategy followed in this research is fundamental in nature as it adds to the general body of NPD knowledge (Page & Meyer, 2000). Fundamental research is sometimes referred to as 'basic' or 'pure' research. The research is furthermore classified as both business research - aiming to enhance the performance of the business - and management research, relating more to people needs. As such, it takes a generalist approach that addresses issues important to managers, employees, and the organisation.

This study predominantly applies a deductive research design and adopts a mixed-method strategy through the combination of quantitative survey and qualitative case study methods for data collection, in this order. Detailed discussions on the survey and case study methods used in this research follow in Sections 4.4 (p. 72) and 4.5 (p. 87), respectively. This approach is justified as it often makes sense to conduct exploratory studies as a first step in a research project in developing new theories or models that have broad applicability (Page & Meyer, 2000). However, the various research strategies used in this research are not mutually exclusive, as according to Yin (2003), each strategy can be used in an exploratory, descriptive, and explanatory manner (which often is the case with this research).

The final sample of 99 firms that were included in the survey research consists of 64.3% firms in the 1-19 full-time equivalent (FTE) staff category; 26.8% in the 20-99 FTE category; and 8.9% in the 100+ FTE category. I purposely included firms in the latter two categories for two reasons: (1) in terms of New Zealand standards, these groups of firms may be considered large, but in world terms they still fall in the relative small-firm category – thus fitting the criteria of this research; and (2) by including these firms it gave me the opportunity to explore the association of firm size (within the small-firm context) as independent variable with tool adoption as dependent variable. This research design is consistent with that of my 5-firm case study research in which I included one relatively large company in the 100+ FTE category to compare tool-use aspects with the two firms in the 1-19 FTE category, and two firms in the 20-99 FTE category.

1.4 Research Questions

The central question of this research is how small high technology firms can better select and use NPD tools in developing new products more effectively and efficiently. Following on from past NPD tool research (Chapter 2) and using the schematic presentation of the eight main tool research areas (Figure 2, p. 13), I separate the research questions below according to the mixed-method research strategies that I followed in this study. (Each of the eight research areas has a corresponding research question, as summarised in Table 6 (p. 43).)

Research questions predominantly suited to quantitative survey research

RQ1: To what extent do practitioners adopt and use tools or categories of tools in their NPD projects? (What are the patterns of tool adoption?)

RQ2: What factors determine tool adoption?

RQ3: What are the major obstacles to tool adoption?

RQ4: Does the use of NPD tools relate to NPD performance?

Research questions predominantly suited to qualitative case study research

RQ5: To what extent are practitioners familiar with the tools they use?

RQ6: Why do practitioners use tools?

RQ7: How do practitioners apply tools in practice?

RQ8: How do practitioners experience tool application?

According to Miles and Huberman (1994) research questions may be general or particular, descriptive (exploratory or explanatory), facts that are most evident from the list of questions. A distinguishing factor of this research is that all of the questions are framed within the small, high technology firm setting. The literature review (Chapter 2) derives investigative questions and where appropriate, sets of hypotheses, for each research question.

1.5 Assumptions

The research of this thesis used the following assumptions:

1) New products are developed within the context of organisations. An organisation may have developed only one product, a series of products in only one product line, or a series of products in more than one product line. Irrespective of the number of products or product lines, each new product is assumed to have emerged from the successful completion of a development project.
2) Each NPD project has gone through a particular development process, be it formalised or of an informal nature.
3) Each NPD project has been assisted by one or more NPD tools (intentionally or unintentionally).
4) Each NPD project has been developed according to some predetermined metrics or project goals.

1.6 Delimitations

The following points set the limits or boundaries of this research, while Section 4.6 p. 98 details its methodological limitations.

1) In this thesis, any reference to small firms implies small high technology firms.

2) The thesis's contribution to knowledge is generic and it is not (and overall does not purport to be) about New Zealand per se. New Zealand's particular composition of firms, with 96% of firms employing 19 or fewer full-time equivalent staff (Jones, 1999), and its accessibility to the researcher makes it an ideal and convenient test bed for studying small-firm practice.

3) This research is only concerned with one particular aspect of innovation management, namely the use of NPD tools. While the influences of NPD process and innovation strategy on the use of NPD tools are investigated to some degree, a detailed study of

these constructs fall outside the scope of this study.

4) It is practically impossible for any researcher to study all available NPD tools, hence this study is only concerned with a selection of tools that I have found to be most popular in the extant literature.

5) On the whole, this study does not purport to be a detailed investigation into the composition or usage of any particular tool. Any reference to specific attributes or use aspects of individual tools merely exists in support of observed phenomena related to the research questions.

6) The research furthermore only considers tool usage within the context of new product development projects at the systems level within small high technology firms, thus excluding component level innovations.

7) I limit this study to measuring the perceptions and actions of only members of the core NPD teams, not members belonging to extended teams.

8) I acknowledge there may be more NPD tool themes than the eight themes I identified in Section 2.6. However, for the purpose of this study I limit my investigation to these eight themes as they provide a good overall coverage of the field of study and they are covered to varying degrees by past research.

9) I do not study actors' motivations or even the outcomes of their actions directly. However, my study goes further than other studies in looking at the 'how' and 'why' aspects of tool use, albeit within the limits set by my methodological considerations.

1.7 RESEARCH CONTRIBUTIONS

The main contribution of this thesis is that it provides a direct answer to the primary research question by integrating the findings of the survey (Chapter 5) and case study (Chapter 6 and 7) research in Chapter 8. Apart from alerting managers and practitioners to useful insights and practices that may potentially improve their chances of NPD success, the findings may also contribute towards a better understanding among academics and consultants on how to best approach and educate managers and innovators on effective NPD tool selection and use. As Brady, et al. (1997) comments, academics are well placed to independently and impartially test and validate tools, and identify gaps in the tools portfolio or market.

While the stream of research related to NPD tools is fairly well developed in the literature, I meticulously point out in the literature review chapter (Chapter 2) a number of gaps that exist.

In the final chapter, I show how these gaps have been closed through empirical investigation in this study.

Other contributions of the thesis reside in a number of developed frameworks and some general findings that provide useful insights to practitioners and academics alike. While the final chapter details such contributions, I mention some prominent ones here. Probably the main differentiating factor of this study is the systematic and inclusive use of 12 perspectives on the NPD process, which resulted in the inclusion of a far larger scope of activities and tools than in any past research. Section 2.2.6 (p. 22) explains the rationale behind the 12 perspectives, while Section 5.2.4 (p. 110) and Sections 5.2.13 to 5.2.16 provide the empirical findings of tool adoption and performance profiles. As opposed to previous studies that were carried out on specific aspects of tool selection and use in a very fragmented manner, the current study comprehensively covers the eight main areas of tool research, as conceptualised in the integrative research framework (Figure 8, p. 68). Consequently, this thesis succeeds in painting as complete a picture possible of tool usage within small high technology firms.

Where past research mostly aims at uncovering relationships between independent and dependent variables without making any attempt at determining causality, this thesis addresses causality in a number of areas by combining case and survey findings. One example is the identification of factors that have the potential to mediate tool performance (the practice through which a tool is internalised in the firm (Section 7.1, p. 200); the degree of tool formalisation (Section 2.2.3, p. 15); various forms of tool adaptations (Section 7.5, p. 224); and thoroughness of tool usage (Section 7.5, p. 224). Other examples include a model explaining why practitioners use certain categories of tools at different stages in an NPD firm's development (Section 7.4, p. 215); and sets of circumstances explaining why tools are sometimes used more thoroughly than at other times (Section 7.5, p. 224).

1.8 Outline of Thesis Chapters

This thesis has eight sequential chapters depicted in Figure 1. The first chapter provides an introduction and brief overview of the contents and direction of this research. The research questions are stated, the thesis is justified, research assumptions are made and boundaries defined.

The second chapter provides a comprehensive review of the literature related to three key areas: NPD tools (which include the development of a tool taxonomy that serves as basis for the questionnaire development), NPD in small firms, and eight prominent areas of tool research that form the basis of this study. It also frames NPD tools within the broader organisational context of innovation. To facilitate the construction of the survey questionnaire, this chapter derives a suitable tool taxonomy and multi-perspective NPD activity framework from the extant literature. A further purpose of this chapter is to develop sharper and more insightful questions about the topic and identify gaps in the literature that the research will close through empirical investigation.

Chapter 3 draws on the strategy-as-practice literature to propose a conceptual model of the relationship between tools, practices, praxis and practitioners. This model demonstrates the contribution that tools and practices make to NPD activity and outcomes and lays the foundations for the case study part of my research (Chapters 6 and 7) that focuses on aspects of tool usage. This chapter furthermore suggests an integrative framework that seeks to unify the empirical findings of this study.

The fourth chapter provides a comprehensive review of the mixed-method research methodology: (1) The survey instrument focuses on the 'who', 'what', 'where', 'how many' and 'how much' quantitative-type questions at the project level (the unit of study is a single NPD project that was completed in the last four years). At times, these questions uncover both similar and different patterns in tool application and use between small and large firms. Also included in the methodology section is an overview of the research measures and analysis techniques used. (2) Following from this, the purpose of the five case studies is to study the remaining aspects of tool application that were not possible to study with survey research, as well as probing deeper into the phenomena that were observed from the survey findings, answering the 'why' and 'how', more qualitative-type questions. The chapter also outlines the survey population and sample characteristics, and provides justification for the selected case studies. It concludes by stating the limitations of both research methodologies.

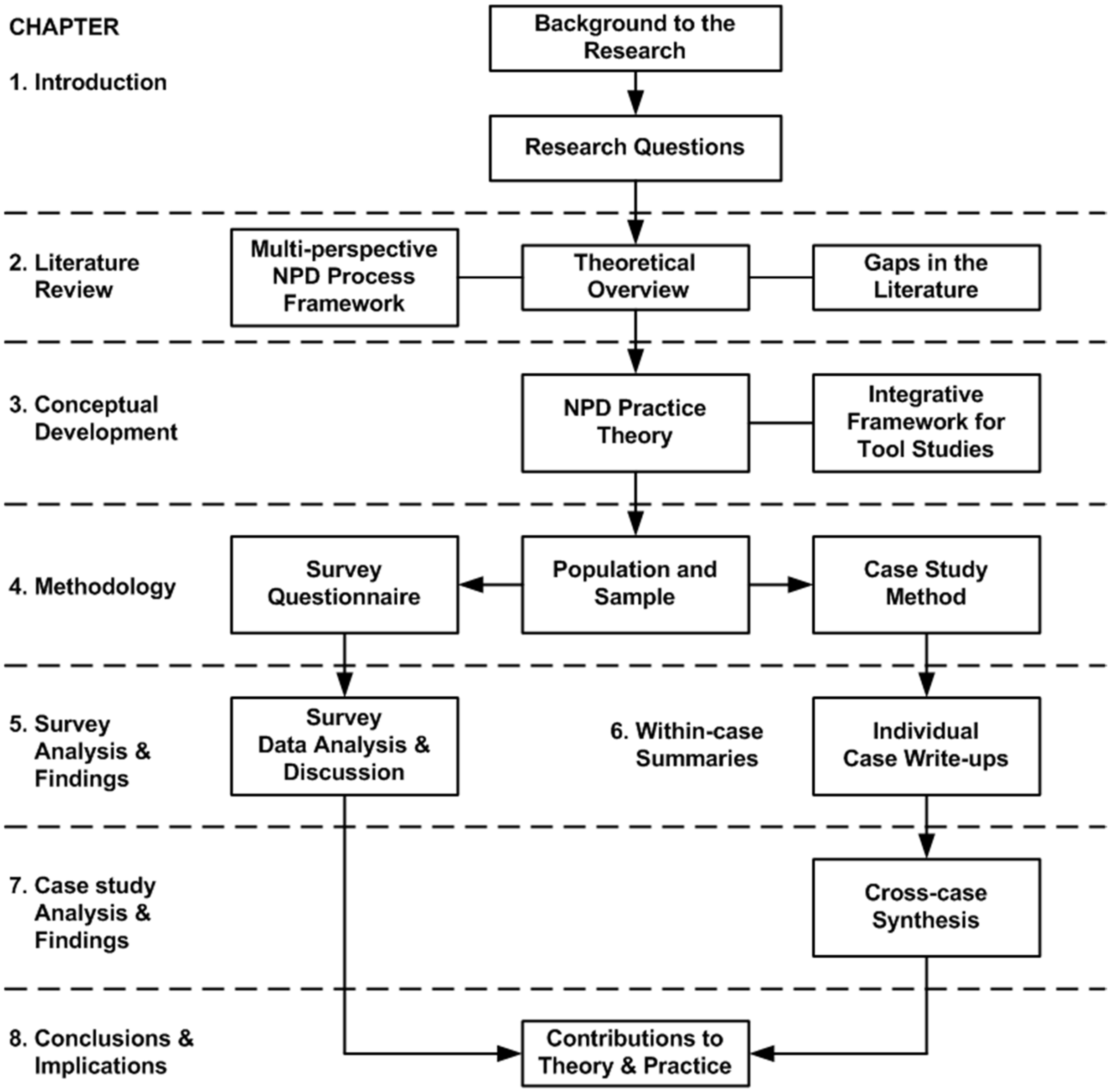
The fifth chapter presents the empirical results of the survey in line with the organising framework that I developed in Figure 2 (p. 13). This includes testing in excess of 20 hypotheses in order to determine whether the observed patterns in the sample also exist in the small-firm population at large. In analysing the survey data I used both descriptive methods and inferential statistics (using SPSS 17.0) such as bivariate methods of association and parametric methods that include cluster analysis and non-parametric exploratory factor analysis. Where appropriate, I restate each hypothesis and contrast my findings against the literature discussed in Chapter 2.

Chapter 6 provides the within-case summaries of the five companies that formed part of the case study research. In this chapter, I made extensive use of NVivo 8.0 to condense a huge amount of data into specific nodes that enabled me to do individual case write-ups according to six main themes that follow from the research questions: (1) reasons for using tools; (2) tool adoption process; (3) obstacles to tool adoption; (4) tool familiarity; (5) tool usage; and (6) tool experiences. As the participating firms in this study requested anonymity, at the start of each individual case write-up, I provide the necessary contextual information to enable the reader to grasp sufficiently the context in which the particular project was implemented.

Chapter 7 builds on the previous chapter as it provides the cross-case synthesis, using tools such as pattern matching, flow-charts and data displays. In analysing the data and presenting the findings this chapter follows the same sequence as Chapter 6 according to the six main themes.

The final chapter provides a general conclusion to the thesis's research questions by integrating the questionnaire and case study findings into a cohesive whole. In doing so, it discusses the descriptive and inferential statistics findings of Chapter 5 in conjunction with several developed models of tool application and use from Chapter 7. The chapter ends with a summary of the overall contributions to theory and practice, and recommendations for future research.

Figure 1. Schematic presentation of thesis outline



2 LITERATURE REVIEW

The purpose of this chapter is six-fold. As the focus of this study is on NPD tools, the first objective is to understand what NPD tools are, and what tools and tool categories are considered by academics in this field of study (Section 2.2). This knowledge will enable me to select a comprehensive set of representative tools for inclusion in the survey instrument. My second objective is to contextualise the role of tools in the broader discipline of innovation (Section 2.3). This is important as it positions the thesis in relation to ongoing academic discussion on (1) how to improve innovation and the management thereof in organisations, and (2) how the findings add to the current body of knowledge by closing the gaps identified in my review of the literature. Thirdly, since I am conducting my research among small high technology firms, I will explore this particular contingency's approach to NPD to provide the backdrop against which I conduct this study (Section 2.4). Fourthly, through a systematic review of NPD literature I will derive a framework around eight main themes that not only organises the existing tool literature, but also provides the impetus for my research into tool selection and use (Section 2.1). The tool themes are: (1) adoption; 2) determinants; (3) obstacles to tool adoption; (4) familiarity; (5) reasons for use; (6) usage; (7) relation to NPD performance; and (8) perceived usefulness. The framework will allow me to review the literature and assess the current body of knowledge for each of these themes (Section 2.6). The overall synthesis will expose the gaps in the literature that my research will close through empirical investigation. In the sixth and final instance, this chapter will help me formulate research questions and, where appropriate, propose hypotheses related to the variables of interest.

I begin this chapter by describing the methods employed during the literature review process and by explaining the specific choice of style used for presenting this review. This is followed by a review of the existing literature in line with the stated objectives, in each sub-section pointing out the gaps in the literature and formulating, where appropriate, corresponding research and investigative questions and proposed hypotheses.

It is important to state one caveat before progressing with this chapter. This relates to defining and scoping NPD tools. When is a tool an NPD tool and when is it not? Many scholars have studied NPD tools, but surprisingly none has been prepared to define or scope it. In Section 2.2.2, I attempt to address this gap in the literature by deriving a definition of NPD tools from the extant literature that I follow up with a discussion of five dimensions along which NPD tools can vary. I complete this synthesis of NPD tools by showing some subjective boundary conditions beyond which NPD tools are no longer tools, or beyond which they fall outside the scope of this thesis.

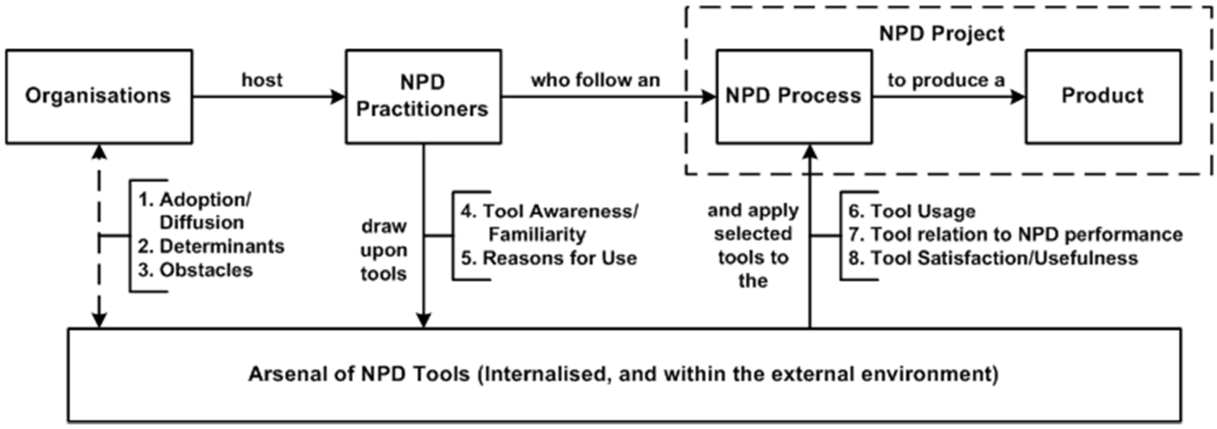
2.1 LITERATURE REVIEW METHODOLOGY

The literature review consists of five areas with the focus on the first and fifth areas: (1) NPD tools; (2) Innovation; (3) NPD in small firms; (4) Factors moderating NPD performance; and (5) NPD tool research areas. I report here only on the methodology used for the first (Section 2.2) and fifth (Section 2.6) research areas as it sufficiently demonstrates the general approach used for all the research areas in this review.

Articles for inclusion in the literature review were first identified by carrying out database searches using the key phrases ‘management tools’, ‘innovation tools’ and ‘product development tools’; and key words ‘innovation’, ‘tools’ and ‘techniques’. I used two databases for this purpose: ABI Inform (Proquest) – limiting the search to business, economics, humanities, science, social sciences, and technology – and Google Scholar. The latter search strategy was useful for rating the relative importance of articles based on the number of citations listed for an article. All searches included full text and were limited to scholarly articles within the past 20 years only. Following a snowball approach, I later added articles from earlier dates and sources that had not been identified in the initial search, reading articles referenced as referring to tools within the papers initially identified.

I initially screened articles by skimming the abstracts before inclusion in my bibliography. The process yielded approximately 40 articles for detailed reading, but the bibliography grew over time as I identified more articles. As I read the articles, I was able to combine and place the fragmented contributions from a relatively small number of scholars in broad categories that I gradually refined into eight main, but often overlapping, themes or areas of NPD tool research at both programme and project levels. I conceptualise the eight research areas in Figure 2 by subscribing to the logic that NPD practitioners (people who engage in the activity of NPD) typically reside within organisations where they follow some form of formalised or informal process to execute a project of which the outcome is a new or improved product. Prior to and during this process, practitioners acquire or build tools with the intention to use them for a given purpose. I acknowledge there may be more than the eight NPD tool themes that I identified. However, for the purpose of this thesis I limit my investigation to these eight themes as they provide a very good overall coverage of the field of study and these themes are fairly well covered in the extant literature. The approach of categorising streams or themes of past research when conducting literature reviews is legitimate and commonly found in journals that publish authoritative reviews. The work of Brown and Eisenhardt (1995) (a literature review published in The Academy of Management Review) is a good example of this, and I base the format and style of my literature review predominantly on theirs. This choice is very appropriate as, similar to Brown and Eisenhardt's, my field of study is highly fragmented, hence the highly structured approach. Yet another style feature that I borrow from these authors, is where their review of the product development literature led them to formulate an integrative model of the topic under consideration, for guiding future research. In similar fashion, in Section 2.2.6 (p. 22), for the purpose of my research, I derive a tool taxonomy that includes a multi-perspective NPD process framework (Figure 5, p. 26), from the extant literature. For the sake of brevity and ease of reading, I summarise the example sets of NPD activities that were required to develop the tool taxonomy in Appendix 1 (p. 292). This taxonomy and frameworks, in conjunction with the rest of my literature review, established the basis for my questionnaire construction.

Figure 2: NPD tool research areas



Furthermore, in line with the University of Canterbury's guidelines on writing literature reviews (http://www.lps.canterbury.ac.nz/lsc/documents/literature_reviews_04_10.pdf), the literature review succeeds in organising and evaluating both the current state of NPD in small firms, and the current body of knowledge regarding tool use in large firms. It does so in a way that logically leads to a set of eight research questions and the formulation of corresponding hypotheses that are clearly framed against the extant literature. It also succeeds in identifying specific gaps in the literature for each sub-section of the review as well as providing a summary of general gaps in the literature at the end of the chapter (Section 2.7, p. 63).

2.2 NPD TOOLS

2.2.1 An Overview of Tools

Before focusing on NPD tools later in this section, it is useful to first review the concepts of management tools and innovation tools, as there appears to be considerable overlap of tools between these categories. Furthermore, management and innovation tools share the same conceptual challenges with NPD tools, which I refer to here and in other parts of the literature review.

Brady, et al. (1997, p. 418) admitted that it is difficult to come up with a precise definition of what constitutes management tools, yet continued to define it as “all the tools, techniques, methods, systems, procedures and methodologies which have been applied to various means of assisting organisations to achieve particular objectives”. These authors argued in favour of this ‘loose definition’ as, in practice, references to these concepts appear to overlap considerably and are often used interchangeably - “a management tool could be document, a framework, procedure, system or method which enables a company to achieve or clarify an objective” (Brady, et al., 1997, p. 418). More difficulty is encountered when attempting to categorise management tools, as individual tools often serve multiple purposes in different areas of application such as strategy, marketing, manufacturing, etc. Brady, et al. (1997, p. 419) commented appropriately that “there is no single or best way of classifying management tools” and “categorisations will depend on the task at hand”.

Innovation tools can be seen as a sub-category of management tools where the ‘task at hand’ is to renew what the organisation offers (refer to the definition of innovation in Section 2.3). It goes by different names as the following examples of interchangeable use demonstrate. Brady, et al. (1997, p. 421) preferred using the term ‘technology management tools’ and defined it as “tools related to decision making and support around activities associated with innovation”. Hidalgo and Albors (2008, p. 117), on the other hand, introduced the concept of IMTs - innovation management techniques and tools - which they defined as “the range of tools, techniques and methodologies that support the process of innovation in firms and help them in a systematic way to meet new market challenges”. Tidd, et al. (2005, p. 348) simply used the term ‘innovation tools’ and defined it as “structured aids to help analyze (diagnose) and act (implement) in managing the innovation process”.

Within the category of innovation tools, it is possible to distinguish among three types of tools depending on their level of use. The first type or category relates to tools that are used at the enterprise/programme level - tools that assist the higher echelons of management in building and sustaining an innovative organisation (e.g. ‘innovation capability assessments’, ‘innovative incentive schemes’, ‘SWORD’, ‘portfolio analysis’, ‘stage-gates’, etc.). The second level relates to tools being used by teams at the project level (e.g. ‘teambuilding’, ‘project intranet’, ‘design review meeting’, ‘alpha prototype’, ‘process charts’, etc.). Arguably, depending on the size of teams, a third level consists of tools being used by individual team members; tools such as ‘customer satisfaction tracking’, ‘lead user’, ‘checklists’ and tools purposely designed by individuals to assist some aspect of their individual responsibility. Note that the concept of innovation tools includes all tools that bear relevance to Kotelnikov’s (2008a) seven areas of systemic innovation (see Section 2.3.2), of which product innovation is but one.

2.2.2 NPD Tool Definition

In this study, the specific ‘task at hand’ is product development, a particular sub-set of tasks within the broader scope of systemic innovation. NPD tools are therefore a sub-set of innovation tools and naturally, management tools. A scrutiny of the NPD literature surprisingly revealed no attempt at defining NPD tools. For the purpose of this thesis, I provide an operational definition for NPD tools that is broad enough to cover most of what the conceptual writers are referring to in their research:

> *NPD tools are any structured aids, managerial or technical in nature, used for structuring or influencing the management and effective execution of the NPD process, its associated activities, and outcomes.*

2.2.3 Ambiguity Surrounding the Definition of NPD Tools

As alerted to earlier, some ambiguity exists surrounding the conditions when a tool can be considered an NPD tool, and when not. For the purpose of this study, I judged tools by five dimensions that I elaborate on next. The first dimension in this tool definition relates to the particular nature of an NPD tool, whether its use is predominantly managerial, or technical. Product development is a multi-disciplinary and multi-functional activity (Phaal, Farrukh, & Probert, 2006) that not only draws on various management and innovation tools from within the various organisational disciplines where and when appropriate, but also on technical tools such as ‘computer aided design’, ‘design mock-ups’, ‘prototyping’, ‘computer aided manufacturing’, ‘video conferencing’, ‘project intranet’, etc. As such, various researchers (Adams, 2004;

Araujo, Benedetto-Neto, Campello, Segre, & Wright, 1996; Tidd & Bodley, 2002; Yeh, Yang, & Pai, 2008b) have been found to include technical tools in their NPD tool studies. My research follows the same approach.

The second dimension of NPD tools is scale. I attempt to clarify what I mean by this by means of some practical examples. The tool 'selection matrix' is ideal for this purpose. Practitioners normally use it when carrying out the activity/procedure of screening different product concepts (it must also be said that practitioners can avoid using this tool and still get an outcome by simply listing a number of possible concepts and intuitively or otherwise select the seemingly 'best' options). It is a tool because it is structured (users must follow certain steps in constructing the matrix, e.g. determine selection criteria, identify different concepts, etc.) and it serves a purpose (it provides a visual quantification of various criteria and concepts). Thus, in its simplest form, a tool can be an aid (e.g. 'selection matrix') that forms part of a single step 'prepare the selection matrix'. However, this same tool can also be part of a procedure (a more encompassing tool), in this case 'concept screening'. 'Concept screening' is a procedure consisting of six separate potential steps (prepare the selection matrix, rate the concepts, rank the concepts, combine and improve the concepts, select one or more concepts, reflect on the results and the procedure) of which the purpose is to narrow the number of concepts quickly and to improve the concepts (Ulrich & Eppinger, 2008). Yet at a higher level the tool 'concept screening', together with numerous other tools or procedures, constitutes the NPD process. As such, the NPD process is also a tool as it can be structured and it serves a definite purpose. In terms of scale, tools can therefore exist as a single aid (the smallest scale), a procedure (medium scale), or a process (large scale).

The third tool dimension is apparent from the word 'structured' within the above definition, which implies that NPD tools generally provide step-by-step approaches to completing certain activities (Ulrich & Eppinger, 2008), to which a certain degree of complexity is associated. I refer to this as the scope dimension of NPD tools, characterised by structure, sophistication and complexity. An electronic calendar, for example, would not qualify as an NPD tool even though it may be used for scheduling NPD activities, as its associated degree of complexity is insignificant; has insignificant scope. Obviously, every tool will differ in complexity from another. For example, 'brainstorming' has much less complexity or structure than 'TRIZ'. What is more compelling, though, is that most tools can be structured at various levels of sophistication or complexity within different organisations, or when used by different practitioners within the same organisation, depending on what level of detail the steps are defined or automatically assumed, for a particular tool. To explain this, I again use the example of 'concept screening': One firm may wish to incorporate all of the six steps listed earlier in its 'version' of the tool, while another firm may choose to omit step 4 (combine and improve the concepts) and step 6 (reflect on the results and the procedure). Clearly, the former case reflects more sophistication than the latter, but the fact remains that both firms can be said to be using 'concept screening'. The same argument holds true for a tool such as the NPD process: Even though there are so many types of process, or process designs, each consisting of different steps, they all qualify in this dimension as an NPD tool providing that it is of considerable or significant scope. Another example is the tool 'project management' (PM). At one extreme, i.e. for very simple products consisting of a handful of components, a company may structure its use of this tool by simply scribbling some notes on the back of an envelope. In the context of this thesis, I consider this to be of insignificant scope, hence not acknowledging the use of 'PM' as a tool. Tools that fall within the next two levels of scope, considerable scope and significant scope, do qualify as tools. An example of considerable scope is a firm that structures its use of 'PM' by means of self-developed spreadsheet models, which may or may not be sufficient for its intended purpose. In the significant-scope category is a firm that uses selected features of a professional 'PM' software package such as MS Project for managing projects of a more complex nature. As these examples show, it is of no relevance whether a tool has been designed from scratch, whether it is free or proprietary or 'opensource', for it to be classified as a tool having sufficient scope.

The fourth dimension of NPD tools stems from the suggestion, implicit in the tool definition, that when practitioners use a tool, they are to some degree consciously aware of the steps and principles employed by the tool, and the tool's purpose. This aspect of tool consciousness is not to be confused with consciousness of tool implementation - the former reflects a situation where a user would be able to, in hindsight, identify a specific tool that was being used in a particular situation, while the latter is reminiscent of a situation where a user becomes so used to a tool that while using it (during implementation) he/she is not consciously aware of the fact that a certain tool is being used. An analogy of this would be a person driving a car (tool) each day to work, this person would do so automatically and not each day consciously think, 'I am driving my car to work'. However, if asked, this person would know for sure that he/she uses a car for this purpose. As such, there is a certain degree of formalisation associated with, and required for, a tool's existence, which I refer to as the dimension representing the degree of tool formalisation. This dimension is closely linked to the dimension of scope, as the following example demonstrates: it is difficult to argue that a practitioner, who engages with customers in an unstructured and informal manner in the course of normal activities and collects information regarding a specific product, is using the ‘voice-of-the-customer’ tool. Similarly, teams making design decisions in an ad-hoc manner as new information happens to become available, cannot be said to be using ‘design reviews’. Clearly, in both examples there was no conscious thought given to any form of structured tool use. (A side-note to these examples is that it is quite possible for practitioners not to use a particular tool and still obtain an outcome, which may or may not be a satisfactory outcome.)

The fifth and final dimension of NPD tools relates to its level of use - enterprise, project, individual - within the organisation, as explained with innovation tools (see Section 2.2.1, p. 14).

In Table 1 I provide a summary of the five dimensions along which NPD tools vary, also indicating the boundary conditions for a tool to qualify as an NPD tool in this thesis.

Finally, I use four different approaches to the NPD process as described below (Adams, 2004) to demonstrate schematically in Figure 3 two of the dimensions of this tool:

- Company A follows no standard approach to NPD;
- Company B has no formally documented process, but there is a clearly understood path of the NPD tasks to be completed;
- Company C has a formally documented process in place where one function completes a set of NPD tasks, then passes the results on to the next function which completes another set of tasks;
- Company D has a formally documented process in place where a cross-functional team completes a set of NPD tasks, management reviews the results and gives the go-ahead for the team to complete the next set of cross-functional tasks.

Clearly, Company D’s approach is the most structured of the four as it represents the highest level of process sophistication and formalisation, and very likely, the biggest number of steps and activities. On these measures, Company C closely lags Company D. Company A has no structure at all and is therefore unquestionably not using this tool, while there is a question mark over Company B’s use of this tool. The two shades of grey in Figure 3 reflect the uncertainty that exists at times in this type of study in deciding whether an entity is using a particular tool, or not. It is problematic because research instruments such as questionnaires and interviews are unable to capture accurately, beyond any doubt, that a tool's steps were actually followed. I acknowledge this problem as an insurmountable limitation in this and similar studies.

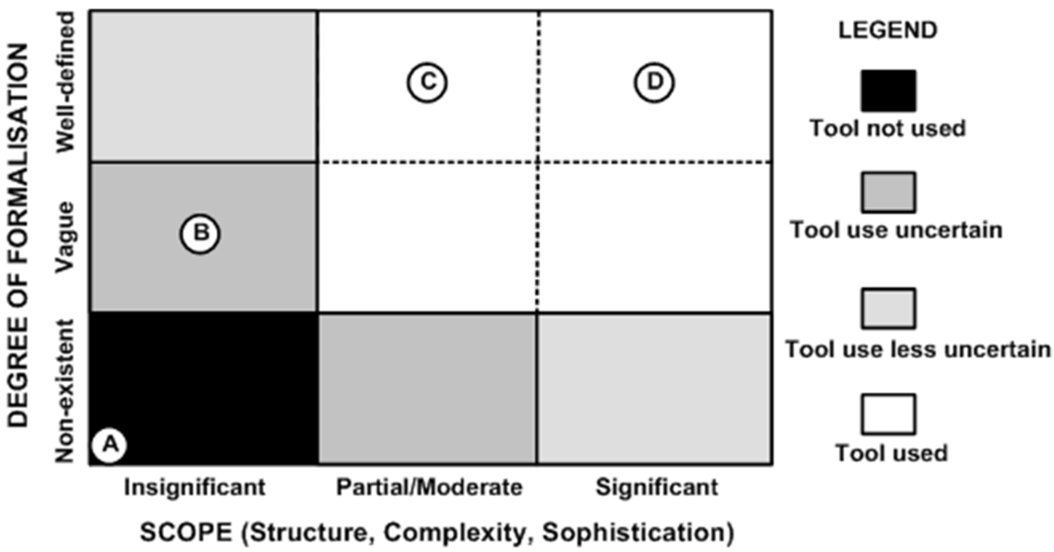
Table 1: NPD tool dimensions and characteristics

Dimension	Description / characteristics	Range	Qualify as NPD tool	Within the scope of thesis
1. Nature	Managerial versus Technical	One or the other	Yes, both types	Yes
2. Scale	Degree of involvement	Small (single aid) Medium (procedure) Large (process)	Yes Yes Yes	Yes Yes Yes
3. Scope	Degree of complexity, structure and sophistication	Insignificant Partial/moderate Significant	No Yes Yes	With reservation* Yes Yes
4. Formal-isation	Degree of conscious tool awareness	Undefined/zero Vaguely defined Well-defined	No Uncertain Yes	No Yes Yes
5. Level of use	User types	Enterprise Project Individual	Yes Yes Yes	Limited† Yes Yes

* 'Tools' of insignificant scope were purposely excluded from the questionnaire, but during the interviews some such tools may have been referred to by practitioners who obviously regarded them as legitimate tools (hence my decision to include such references for completeness sake).

† As I have indicated before that my unit of study is a single NPD project, I should technically study only NPD tools that fall within the 'project' and 'individual' ranges. However, as I have indicated with the word 'limited', I do include a select few tools at enterprise level, as these tools have the potential to impact project-level success and therefore I want to investigate their impact at this level. Tools in this category include portfolio analysis, innovation strategy, marketing plan, real options theory, and total quality management.

Figure 3: Depth of use of the 'NPD process' tool



2.2.4 NPD Tool Categories

As there are a multitude of NPD tools available to practitioners, selecting the most appropriate one for a particular task becomes a difficult challenge. Hence, it would be useful to order them in a way that makes it easy for practitioners to select the right tool for a particular task, and for scholars to study tools in a structured and logical manner. A number of scholars have attempted to do just that. Nijssen and Lieshout (1995), for example, classified what they regarded as the most popular tools into the four categories of idea generation, product optimisation, marketing-mix optimisation, and prediction. They base this categorisation on what they consider the four underlying problems of NPD. Adams (2004), on the other hand, also used four, but different categories: market research, engineering-R&D & design, technology, and team support. Other categorisation attempts include that of Tidd, et al. (2005, 2008a, 2008b) who used no less than three categorisation schemes on different occasions (see Table 2).

Because the NPD field lacks a widely accepted, comprehensive organising framework, researchers often define their own schemes such as the ones listed above, and these tend to be both limited in scope and hard to integrate with one another. These schemes are not suitable to function as a taxonomy for studying tool usage as they are either too narrow in scope (excluding certain types of tools), too simplistic (not useful), or just outright confusing (difficult to grasp when and where to use the tools).

Table 2: Tidd, et al.'s categorisations of NPD tools

Unknown logic (2008a)	**By Process Stage** (2005)	**By Theme** (2008b)
• Audit, diagnose, position • Creativity • Future-focused • Implementation • Inward-focused • Learning and evaluation • Outward-focused • Problem solving • Structured, integrated programmes • Total Quality Management	• Searching • Selecting • Acquiring • Executing • Launching • Sustaining • Learning	• Developing an innovation strategy • Effective implementation mechanisms • Clear strategic focus and commitment • Effective external linkages • Supportive organisational context

This makes it difficult to synthesise individual research findings into a coherent body of knowledge. For example, Nijssen and Lieshout's (1995) categorisation based on solving NPD problems excluded tools designed for other purposes, while none of the proposed categories covered tools for key NPD activities such as project management, product strategy, or information management.

2.2.5 Which Tools to Include in the Study of NPD Activity?

As there are a multitude of NPD tools available to practitioners, the question arises which ones to include in a study of this nature, bearing in mind the inherent time and length limitations of most measuring instruments and the impracticality of questioning practitioners on too large a number of tools. As a first resort, I reviewed the extant literature to determine which tools other researchers have included in their studies. As can be seen from Table 3, the number of tools studied varies greatly between six and 45 tools. These individual research efforts do not address the full scope of tools that practitioners can use in NPD. Instead, they focus on limited selections of tools, types of tools, and application areas – primarily in the areas of engineering, design, creativity and market research – which do not do justice to the multi-functional nature of NPD.

In relation to individual activities and associated tools, I furthermore found that the literature has little overlap between studies. In a sample of 11 papers reporting tool research (Adams, 2004; Araujo, et al., 1996; Chai & Xin, 2006; Mahajan & Wind, 1992; Maylor, 2001; Nijssen & Frambach, 1998, 2000; Nijssen & Lieshout, 1995; Thia, et al., 2005; Tidd & Bodley, 2002; Yeh, et al., 2008b), I found that with few exceptions each study focused on its own unique set of tools. The only consistent tool in all 11 studies was 'quality function deployment'. Only four other tools - 'focus groups', 'brainstorming', 'conjoint analysis', and 'concept testing' - were included by more than half of the studies.

The mentioned shortcomings regarding the decision of which tools to include in past research prompted me to follow a three-thronged approach to selecting a set of commonly used tools that arguably represents all major activity areas within NPD. In the next section I firstly derive, from the extant literature, an NPD activity framework consisting of four process stages and 12 different perspectives to NPD. I then conduct a review of NPD literature to populate each process stage and perspective with typical activities, in the final instance, to enable me to identify and organise corresponding tools for possible inclusion in my study.

Table 3: Sample summary of scholarly research on NPD tool use

Scholars	Country of research	Research characteristics
(Mahajan & Wind, 1992)	USA	Fortune 500 firms, N=78, 24 tools
(Nijssen & Lieshout, 1995)	Netherlands	Industrial firms, N=75, 23 tools
(Araujo, et al., 1996)	United Kingdom	Aeronautical, automotive and general electrical/mechanical firms, N=27, 13 case studies, 31 tools
(Nijssen & Frambach, 1998)	Netherlands and Belgium	Market research firms, N=35, 10 tools
(Nijssen & Frambach, 2000)	Netherlands	Industrial firms, N=62, 13 tools
(Maylor, 2001)	England	Manufacturing firms, N=34, 21 tools
(Tidd & Bodley, 2002)	United Kingdom	Chemical, pharmaceutical, consumer, durables, food. N=25, 6 tools
(Farris, Hartz, Krishnamurthy, & McIlvaine, 2003)	USA	Software tools for the web-enabling of innovation process, conference attendees, N=33, 15 tools
(Adams, 2004)	USA	N=416, 45 tools
(Thia, et al., 2005)	Singapore	7 case studies on Industrial firms, 10 tools
(Chai & Xin, 2006)	Singapore	'Singapore 1000' industrial manufacturing firms, N=67, 10 case studies, 8 tools
(Yeh, Yang, & Pai, 2008a)	Taiwan	High-tech manufacturing firms, N=88, 26 tools
(Hidalgo & Albors, 2008)	European Union	Manufacturing firms, academic centers, business schools, consulting firms, business support organisations, government agencies. N=426

N = sample size

2.2.6 Deriving an NPD Tool Taxonomy

In my review of the extant literature, I found that past research took a piecemeal approach to viewing and studying the NPD process from limited perspectives. It did not encourage practitioners to take a truly holistic approach to NPD by taking into consideration activities within all the perspectives expressed by NPD scholars. For example, I found that it poorly represented product strategy, manufacturing, team support, learning and review, and decision-making. I also noted that most NPD process models have been observed to exhibit a strong bias towards technical matters (Cooper, Edgett, & Kleinschmidt, 2004c).

An inherent limitation in NPD tool research stems from the absence of a single authoritative NPD process that can serve as a basis for studying NPD tools. In practice, the enacted NPD process will be unique to each organisation and project, and in theory many equally legitimate models exist that describe NPD processes from different perspectives. However, each unique enacted process could draw upon, or be characterised by, the same authoritative integrating framework based on a generic NPD process.

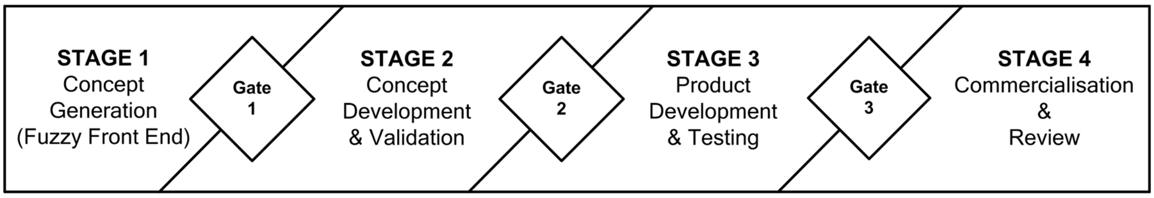
This section adopts a broad definition of the NPD process that covers all steps, activities, and decision points that are involved in the development of a new product – from the initial idea to the product launch and beyond (Cooper & Kleinschmidt, 2007). In this definition, 'steps' include all tasks and responsibilities that are required in the conceptualisation, design, and development of new products (the NPD process) such as 'define market segments', 'estimate manufacturing costs', and 'obtain regulatory approvals'. These steps can be routine or non-routine, formal and informal, and are normally organised into stages or phases that are often interdependent and sometimes overlapping (Adams, 2004). Cooper (1990) developed arguably the most reputable model to structure the product innovation process around various stages and stage gates for taking a product from mind to market. The original trademarked 'gate' concept today goes by different names: phase review, phase gate, kill points and quality gates (Valeri & Rozenfeld, 2004).

Since Cooper's original model, many others have emerged (Tidd & Bodley, 2002), incorporating any number of stages (or phases as they are often referred to) ranging from three to thirteen or more. Tidd, et al. (2002), for example, used a four-stage model of which the stages are concept generation, project selection, product development, and product commercialisation and review. Koen, et al. (2002), on the other hand, divided the product innovation process into three areas: the Fuzzy Front End (FFE) of innovation, the NPD process, and commercialisation. In this model, both the FFE and commercialisation were seen as something distinct or separate from the actual NPD process, in contrast to the PDMA's definition of NPD. Nijssen and Frambach's (2000) process had eight stages that included idea generation, idea screening, concept development and testing, marketing strategy, business economic analysis, product development, market testing, and commercialisation.

As can be seen from these examples, scholars of innovation often have very different views on exactly which stages and activities to include or exclude in the NPD process, often mixing different perspectives (such as marketing and technical perspectives). Shepherd and Ahmed

(2000) concluded, after having studied numerous frameworks, that there remained considerable scope for improvement. As a first step in developing a generic, holistic and parsimonious framework suitable for studying NPD tools, I draw on the above literature to derive a model that has only four distinct, but overlapping, stages (see Figure 4). Four stages as sufficient, because in the discussion that follow, I draw from the extant literature a comprehensive set of perspectives to expand the model vertically into multiple parallel perspectives of which the associated steps and activities are done concurrently. This multi-perspective approach renders unnecessary some stages mentioned in other models.

Figure 4. A four-stage NPD process model with overlapping stages



Stage 1 is reminiscent of the Fuzzy Front End (FFE) as it is characterised as being experimental, often chaotic, unpredictable, uncertain, non-linear, and variable (Koen, et al., 2002). This stage includes steps associated with Cooper, et al.'s (Cooper, Edgett, & Kleinschmidt, 2002b) 'discovery' stage. Cooper, et al. (2004c) referred to this stage as the pre-development homework stage and identified it as the most problematic in the whole NPD process, but also one in which strong emphasis was found far more often in the best performers than in the worst.

The outcome of Stage Gate 1 is an approved and sufficiently resourced project that needs to be validated technically and commercially in Stage 2 before Stage 3 development work begins. Technical feasibility may involve proof of concept and development of the alpha prototype that may necessitate further research and development (R&D), and concept development. Commercial feasibility includes the assessment of financial and marketing criteria, the latter of which may already involve initial market testing, but only if intellectual property protection has been initiated. Activities in this stage are all geared towards providing sufficient support for gaining approval for product development at Gate 2.

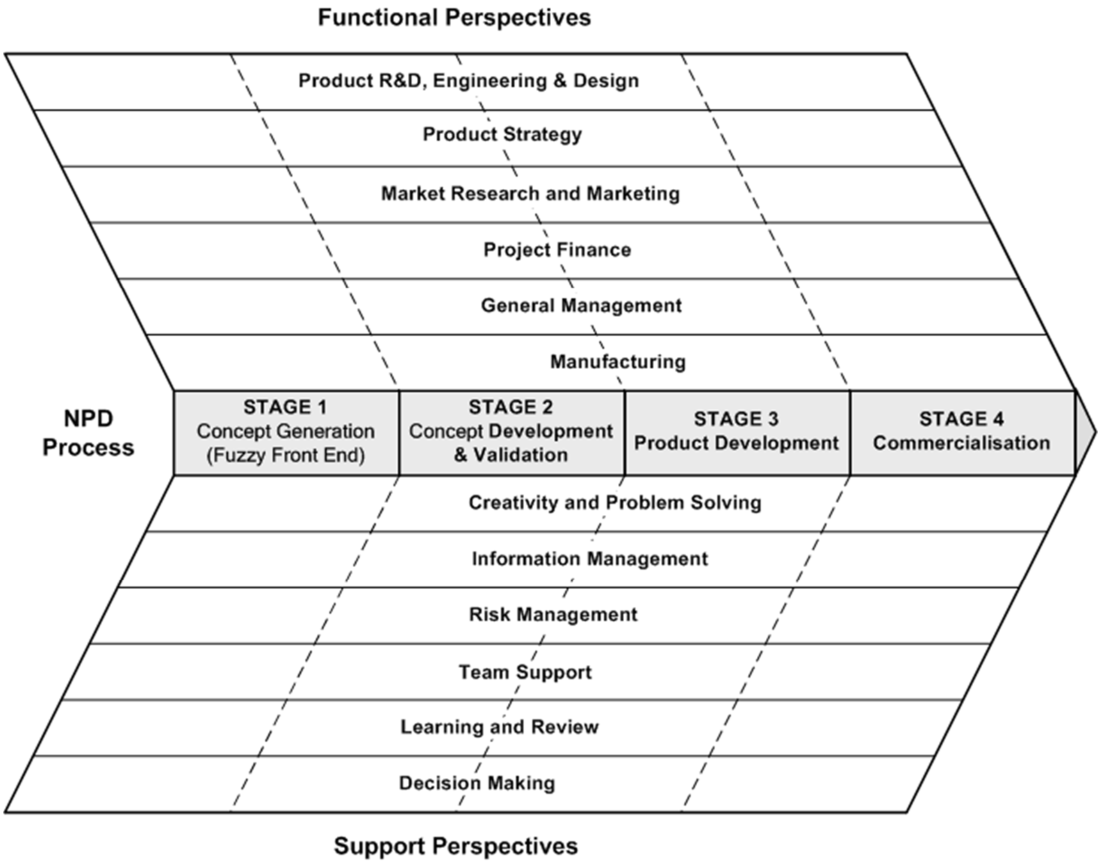
Stage 3 includes both system-level and detail design activities. The former involves defining the product architecture in terms of subsystems and components, while the latter includes the complete specification of the geometry, materials, and tolerances of all the unique parts in the product as well as the standard parts to be purchased from suppliers (Ulrich & Eppinger, 2008).

The fourth stage is termed commercialisation, that part of the NPD process that takes a new product from development to market (PDMA, 2008a). It starts with a fully developed new product that is ready to go into production, having gone through all the required development activities to ensure the product has the best possible chance of being successful, and ends the moment the firm officially launches the product into the market for mainstream sales.

The process model depicted in Figure 4 is useful, but not sufficient, for research into the multidimensional facets of NPD. Similar to most NPD process models that have been observed to exhibit a strong bias towards technical matters (Cooper, et al., 2004c) or 'state of the product' matters (Ulrich & Eppinger, 2008), this model does not explicitly reflect and address other important multi-faceted aspects that exist within the NPD process. Thus, the question arises: which NPD perspectives need to be incorporated into the process model to provide the most comprehensive view of the scope of activities possible?

To answer this question, I reviewed the works of various authors who have attempted to broaden the prevailing way of thinking about the NPD process by including more perspectives in understanding NPD. Andreasen and Hein (1987) integrated three parallel perspectives into their NPD model: product adaptation, production and sales. Ulrich and Eppinger (2008) included the three main perspectives of marketing, design and manufacturing in their six-phase model, but acknowledged the importance of other perspectives such as research, finance, general management, sales, legal, and service. Prebble, et al. (2008) expanded their process to reflect three perspectives which they termed technical & operational, strategic, and commercial, while Ramesh and Tiwana (1999) studied NPD activity from a knowledge-management perspective. Smith and Merritt (2002) emphasised risk management across all functions as an important NPD perspective and Song, et al. (1997) compared the antecedents and consequences of cross-functional cooperation among R&D, manufacturing and marketing perspectives. NPD perspectives highlighted in other studies include team building and support (Inwood & Hammond, 1993), creativity and learning (Corbett, 2005) and decision making (Yahaya & Abu-Bakar, 2007). Through consolidation of the various perspectives, I derived the framework in Figure 5 by adding to the traditional one-dimensional process model the layers of detail required for it to categorise activities and tools. The result is a multi-perspective, two-dimensional framework that takes a holistic approach to NPD. This is an important development, as successful technology management - which includes NPD - is fundamentally multi-disciplinary and multi-functional (Phaal, et al., 2006). True to its integrative purpose, the framework incorporates perspectives that differ widely in level of abstraction and discipline base (e.g. general management versus project strategy versus creativity and problem solving). Clearly, no categorisation is perfect and I acknowledge that another researcher might define and group perspectives differently.

Figure 5. A multi-stage, multi-perspective NPD process framework



For ease of use and understanding, I split the resulting framework into two parts, the one consisting of ‘functional’ perspectives and the other of ‘support’ perspectives. I define each perspective as follows:

1. **Product R&D, Engineering and Design Perspective:** concerned with the physical evolution of the product from idea into concept, through prototype stage into a fully commercialised product.
2. **Product Strategy Perspective:** concerned with the strategic assessment of influencing factors, and the alignment, resourcing, and positioning of the product throughout its entire life cycle.
3. **Market Research and Marketing Perspective:** concerned with extracting, manipulating and negotiating factors related to customers and markets.
4. **Project Finance Perspective:** concerned with achieving favourable economic returns on investment in terms of profitability, growth and shareholder value.

5. **General Management Perspective:** concerned with the efficient planning, organising and controlling of project resources.
6. **Manufacturing Perspective:** concerned with achieving the most efficient and effective transformation of inputs into desired outputs.
7. **Creativity and Problem Solving Perspective:** concerned with stimulating innovative ideas and developing solutions to NPD problems.
8. **Information Management Perspective:** concerned with the creation, storage, arrangement, retrieval, and distribution of information and knowledge among cross-functional team members at the interface between NPD tasks.
9. **Risk Management Perspective:** concerned with identifying and assessing associated technical and commercial risks, and formulating appropriate contingency plans.
10. **Team Support Perspective:** concerned with encouraging and coordinating inter-functional and external collaboration and cooperation.
11. **Learning and Review Perspective:** concerned with exploiting learning opportunities throughout the NPD process in order to achieve shared understanding from which future projects may benefit.
12. **Decision-Making Perspective:** concerned with using the best information possible for making the right decisions at the right time in order to optimise product opportunities.

Each of the 12 areas within the framework represents a specific stage and perspective containing generic sets of activities (described in Exhibits 1 to 12 in Appendix 1, p. 292) comprising the NPD process and associated in the literature with NPD success. Not all projects necessarily pass through every stage or every gate of the framework, and in any project, activities and deliverables can be omitted or bypassed (Cooper, 2008).

In-between the stages are the gates where managers make Go/Kill/Hold/Recycle decisions. While the framework describes a logical progression from the left (mind) to the right (market) through four clearly defined stages, it is important to note its conceptual nature. The activities within the various stages and across the twelve perspectives are not necessarily linear and could very well overlap in practice. I am representing a set of perspectives as a conceptual model to classify activities and not to represent a split of activities between people or functions. It is perfectly possible, for example, to see design engineers carrying out an activity represented under the market perspective.

To complete the multi-perspective NPD framework, I have populated each stage and perspective with existing NPD activities and tools. Exhibits 1 to 12 in Appendix 1 (p. 292) provide example sets of activities within each stage and perspective that I compiled from a thorough scrutiny of scholarly literature. These sets are by no means exhaustive as the intention is not to provide a comprehensive process manual, but to scope the nature of activities in each dimension sufficiently.

By relating the types of activities to accepted tool definitions, in Table 4 (p. 29) I categorise within each of the twelve perspectives a selection of the tools that the scholarly literature often cites. In doing so, I acknowledge that there is no single or best way of classifying tools and that any categorisation will depend on the task at hand (Brady, et al., 1997).

This table is useful as it showcases a comprehensive range of popular tools from all 12 NPD perspectives that can potentially be included in tool research. Tools often serve more than one purpose, but for the sake of brevity I list each tool once only in the perspective where it arguably fits best. I have not classified the tools into the four stages because in practice, tools are flexible. It is not possible to do a one-to-one mapping of tools and activities as managers often apply tools successfully outside the context for which they were originally designed (Mahajan & Wind, 1992; Yeh, et al., 2008b).

2.2.7 Past Research and the Effect of Firm Size

Scholars tended to focus their NPD tool research on tool use in specific countries or major regions of the world, and specific industries. In Table 3 (p. 22), I provide a sample summary of scholarly research conducted in different parts of the world over the past 20 years. The research predominantly involved firms in high technology industries that are considered large in world terms - firms typically employing several hundred or thousand full-time equivalent staff. As Akgün, Lynn, and Byrne (2004, p. 41) commented, “most studies on the critical success factors focus on new product development practices in large firms, ignoring small- to medium-sized enterprises (SMEs) in general”. Early research by Mahajan and Wind (1992) investigated frequently used tools among 200 Fortune 500 firms in the USA. These are major corporations employing hundreds if not thousands of people.

Still in the USA, almost 60% of participating firms in the PDMA Comparative Performance Assessment Study (Adams, 2004) had annual sales exceeding $100million, which is a far cry from the participating firms in this study with approximately 80% generating less than NZ$10million (USD5.8million) annually (refer to Figure 13, p. 83). Research in the

Netherlands (Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995) studied use aspect of tools among huge industrial firms with median number of employees between 200 and 500.

Table 4. Categorised examples of popular NPD tools

1. Product R&D, Design & Engineering Perspective Collaborative Product Development, Computer-Aided Design, Computer-Aided Engineering, Concurrent Engineering, Design for X (DFX), Design of Experiments (DOE), Modular Design, Quality Function Deployment (QFD), Simulation and Electronic Prototyping, Taguchi Method (Robust Engineering), Alpha Prototype, Concept Testing, Design for Six Sigma, Design Mock-up, Product Design Specification, Value Analysis/Value Engineering (VA/VE), Beta Prototype, Rapid Prototyping, Gamma Prototype
2. Product Strategy Perspective Product Innovation Strategy, Portfolio Technique, Success Drivers, PESTE Analysis, Porter's Five Forces, Competitor Analysis, Boston Matrix, Product Naming Methodology, STUP (Segmentation, Targeting, Understanding, Positioning), Co-development Strategy Matrix, Scenario Planning, Confidentiality Agreement/ Non-Disclosure Agreement (NDA), Patent Searching, Provisional Patent Application (PPA), Intellectual Property Protection (Patent, Trademark, Registered Design, etc)
3. Market Research and Marketing Perspective Conjoint Analysis, Discrete Choice, Ethnography, Voice-of-the-Customer (VOC), Diffusion Models, Lead user, Needs Analysis, Beta Testing, In-Market Testing, Limited Roll-out/Test Marketing, Marketing Plan
4. Project Finance Perspective Financial Models (ROI, IRR, NPV, DCF, Breakeven Analysis), Sales & Cash Flow Forecasting, Productivity Index
5. General Management Perspective Concept Statement, Project Planning & Management, Critical Path Analysis, Project Management, Feasibility Study, Business Case, Enterprise Resource Planning (ERP), Total Quality Management (TQM), Manufacturing Resource Planning (MRPII), Materials Requirement Planning (MRP)
6. Manufacturing Perspective Group Technology, Statistical Process Control (SPC), Process Mapping, Computer Integrated Manufacture (CIM), Computer Integrated Production (CIP), Computer-Aided Manufacturing (CAM), Process Flow Diagram
7. Creativity and Problem Solving Perspective Brainstorming, Expert Opinion, Delphi Method, Focus Group, Ishikawa (Fishbone Analysis), Morphological Analysis, Pareto Analysis, Product Life Cycle, Roadmapping, Synectics, Theory of Inventive Problem Solving (TRIZ), Technology Trend Analysis and Forecasting
8. Information Management Perspective Document Management System (DMS), Electronic Data Interchange (EDI), Knowledge Management (KM), Project Intranet, Change Control System, Engineering Drawing to BS 308, Product Data and Configuration Management (PDCM), Configuration Management System (CMS), Databases and Data Mining
9. Risk Management Perspective Failure Mode Effects Analysis (FMEA), Fault Tree Analysis, Market/Computer Prediction Models, Risk Assessment Matrix
10. Team Support Perspective Gatekeepers, Cross-functional Teams, Tele-conferencing, Video-conferencing, Design Review Meetings, Workflow, Teambuilding, Team Launch System (TLS)
11. Learning and Review Perspective Expert Systems, Benchmarking, Artificial Intelligence, Balanced Scorecard, Customer Satisfaction Tracking, Malcolm Baldridge Awards Framework, Post-Launch Review, Post-Project Review
12. Decision-Making Perspective Stage Gates, Portfolio technique, Real Options Theory, Checklists, Technology and Product Roadmap Integration, Decision Tools, Selection Criteria

Similar research in the UK and European Union (Araujo, et al., 1996; Balbontin, et al., 2000; Hidalgo & Albors, 2008; Maylor, 2001; Tidd & Bodley, 2002) had research samples where the majority of firms employed several hundred employees. Further east, tool research in Singapore (Chai & Xin, 2006; Thia, et al., 2005) and Taiwan (Yeh, et al., 2008b) also involved samples where the majority of firms employed more than 100 employees. It appears that no NPD tool research has been done among firms employing less than 100 full-time equivalent staff. This is clearly a limitation as many NPD firms that operate in peripheral regions, in networked industries, in highly innovative clusters, and in small-population countries such as Australia, New Zealand, and South Africa, typically are of this size. Even in bigger countries, start-up technology firms often start small and remain so until such time that they are able to break into mainstream markets and expand in size. The question arises whether past research findings apply equally to smaller high technology firms. It is an objective of this study not only to investigate the various aspects of tool application and use among small high technology firms, but where possible, to compare the findings with research conducted among larger firms.

2.3 Innovation

Innovation means different things to different people and has been studied in a variety of contexts, including in relation to social systems, economic development, policy construction technology and commerce (Fagerberg & Godinho, 2004). There is, therefore, naturally a wide range of approaches to conceptualising innovation in the scholarly literature. In this thesis, I focus on the specific role that NPD tools play in the context of innovative organisations of which the development of new products is a main business activity. The purpose of this section is to provide a broad overview of innovation with regard to the categories and types that exist within such organisations, and what management of innovation entails. This overview is necessary for effectively framing the selection and use of NPD tools in the broader organisational setting.

As there is no single authoritative definition for innovation and its underlying concepts, including the management of innovation and innovation tools, any discussion on the topic becomes difficult and even meaningless unless the parties to the discussion agree on some common terminology. Tidd, et al. (2005, p. 40) defined innovation as “a core process concerned with renewing what the organisation offers and the ways in which it generates and delivers these”, while Davila, et al. (2006) viewed innovation, like many business functions, as a management process that requires specific tools, rules, and discipline. These definitions are very much from a practical perspective. One can also approach innovation from a philosophical standpoint as Kuczmarski (1996, p. 7) has done: "Innovation is a mindset – a new way to think about business strategies and practice." He continued saying that although you cannot touch it, smell it, hear it, see it, or taste it, you can sense, think, and feel innovation. "Innovation is best described as a pervasive attitude that allows businesses to see beyond the present and create a future vision."

To emphasise the important role that tools play in innovation, I combine aspects of the above definitions in defining innovation as a creative process, assisted by a variety of tools, to renew what the organisation offers, in terms of new or improved products and/or services and the ways in which it generates and delivers these.

2.3.1 Categories of Innovation

Researchers and practitioners often distinguish between different categories of innovation. Christensen and Raynor (2003), for example, developed the sustaining versus disruptive model of innovation. Sustaining innovations are compatible with existing standards and address the current needs of markets, whereas disruptive innovations render existing standards obsolete and address future needs. Tidd, et al. (2005, p. 73) thought of innovation in terms of two complementary modes, the first of which they term "doing what we do but better", and the second contrasting mode "do different". Other frameworks for innovation include evolutionary versus revolutionary innovation (Abernathy & Clark, 1985) and incremental versus radical innovation (Abernathy & Utterback, 1978). Incremental or continuous innovation represents innovations where the normal technology and/or business rules are further developed along the same lines. Radical innovations, on the other hand, represent clear departures from existing practice and/or revolutionary changes in technology. There is some overlap among these categorisations, but as the following examples show, they do not necessarily always mean the same thing. It is possible, for example, for an innovation to be radical yet still be sustainable. Christensen and Raynor (2003) cited the introduction of the electronic cash register in the 1970s as such an example. Furthermore, what is sustainable for one firm may be disruptive to another. The Internet, for example, proved to be a sustainable technology for Dell Computers who based its business model on it, while it was highly disruptive to other manufacturers of personal computers.

2.3.2 Types of Innovation

Aligned with the idea that organisations should not limit innovation activity to products, services and technologies as is generally the case, but be innovative all across the value chain (Aiman-Smith, Goodrich, Roberts, & Scinta, 2005), Kotelnikov (2008a) introduced what he referred to as the "new era of systemic innovation". This 'systemic' approach to innovation (see Table 5) depicts the evolution of the innovation process away from the old singular and linear view of innovation (predominantly a periodic technological process, driven by technologists, and led by functional experts), to the modern systemic view of innovation where cross-functional synergists continuously lead cross-functional teams across the entire business wheel. The words 'systemic' means "relating to or affecting the entire body …" (TheFreeDictionary, 2008), which, in the case of systemic innovation, implies innovation relating to or affecting the entire organisation. As such, innovation can be applied across many interwoven types or areas within organisations: product/service innovation, technology innovation, process innovation, business innovation, strategy innovation, marketing innovation, administrative innovation, and organisational innovation (Kotelnikov, 2008a; Popadiuka & Choo, 2006).

Table 5: Evolution of the innovation process

	Linear innovation (old view)	**Systemic innovation (modern view)**
Target	Technological process	The entire business wheel
Drivers	Technologists	Cross-functional teams
Lead Innovator	Functional expert	Cross-functional synergist
Process	Periodic	Continuous

(source: Kotelnikov, 2008a)

In this holistic approach innovation is not divisible – 'good in parts' is no good at all (Kotelnikov, 2008b). Innovation systems, consisting of complex interactions between many individuals, organisations and their operating environment, are only as strong as their weakest links.

This research is only concerned with product innovation, which in the strict sense of the word, can be divided into product development (PD) and new product development (NPD). The former is about making improvements to existing products, while the latter implies developing completely new products. Practitioners and academics alike, however, seldom distinguish between the two terms as is evident from how The Product Development and Management

Association (PDMA) define NPD: "NPD is the overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product... also frequently referred to just as product development" (PDMA, 2008b). Ulrich and Eppinger (2008, p. 2) made no distinction between the two concepts in defining product development as "the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product".

As the unit of research in this study is a single NPD project, I am using the category definitions of Booz, Allen and Hamilton (1982) for describing the various types of the new product development projects:

- Radical innovations include New-to-the-World products (also called Breakthrough products);
- More innovative projects include New Product Lines (also called New-to-the Firm) and Additions or Major Revisions to Existing Product Lines;
- Incremental Innovations include Incremental Improvements to products currently produced by an organisation, Repositionings of products currently produced by the organisation, and Cost Reductions of products currently produced by the organisation.

2.3.3 Innovation Management

Key to obtaining better overall innovation results is improving the management of innovation, but organisations often do not recognise the management of innovation as a specific issue or one that they should address systematically (Mogee, 1993). This section provides a broad overview of what innovation management entails and where the use of innovation tools fit into the broader scheme of things.

The notion that innovation can be managed originates from two fronts. The first relates to the process characteristics of innovation (refer to the earlier definition of innovation), as arguably any process can be managed. Secondly, managers manage and teams execute innovation projects within the context of organisations. Therefore, managers can proactively plan, organise, control and lead all aspects of innovation, including the process, and thereby affect the desired outcomes in potentially positive ways. The reality is that innovation is "complex, uncertain and almost (but not quite) impossible to manage" (Tidd, et al., 2005, p. 571). These authors claimed that in conditions of complexity and change, which are reminiscent of managing innovation, there are no easily applicable recipes for successful management practice.

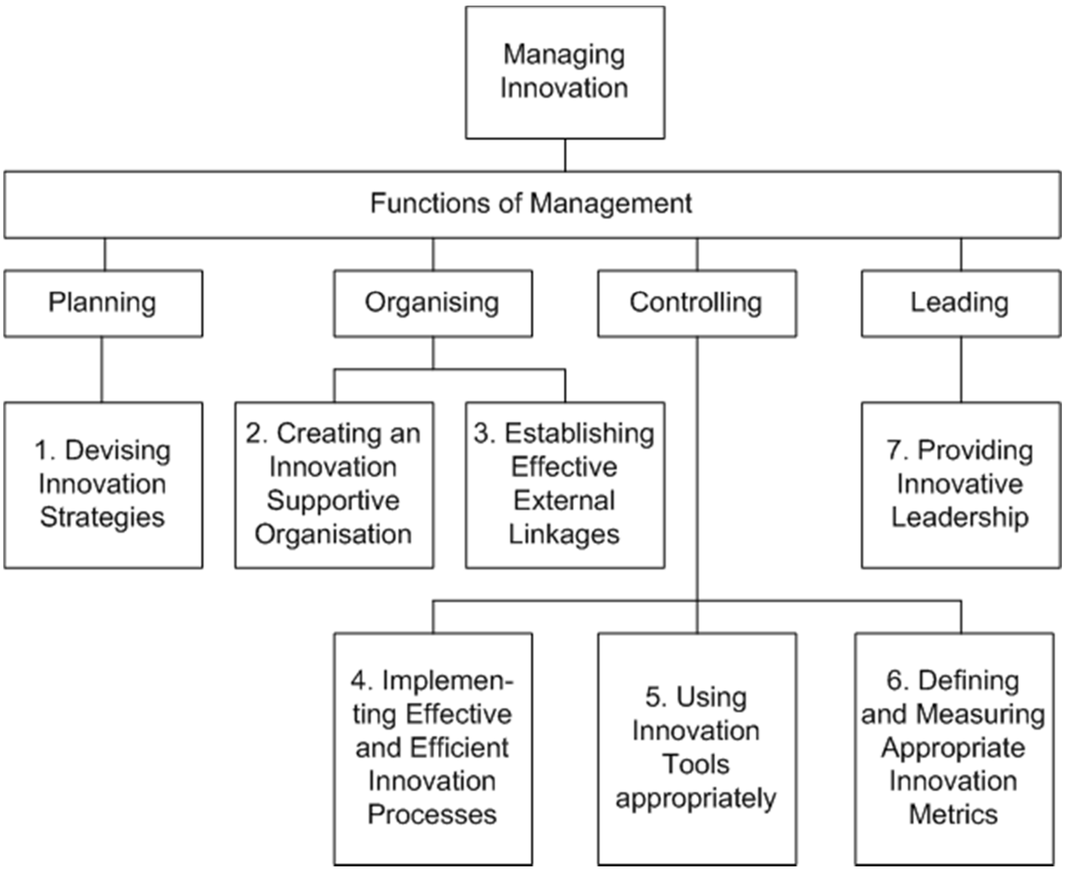
The four-function management theory of Fayol (1949) provides a useful categorisation schema for organising the seven sets of activities that I found, through a review of the literature, that are associated with the management of innovation within organisations. As such, Figure 6 depicts the broad scope of innovation management activities. Fayol's planning function covers the formulation of an innovation strategy for the organisation (Dodgson, Gann, & Salter, 2008; Saleh & Wang, 1993; Tidd, et al., 2005). Section 2.5.2 provides a brief synopsis of innovation strategy. The organising function involves the building of an innovation supportive organisation (Saleh & Wang, 1993). There are many aspects to this facet, as innovation scholars have unveiled numerous factors that, to a greater or lesser degree, have the potential to make organisations more conducive to innovation. For clarity of purpose, I list some factors below:

- A culture that encourages creative thinking, innovation, and risk-taking (Sheppard & Canning, 2006), one that supports and guides intrapreneurial liberty (Jamrog, Vickers, & Bear, 2006) and growing a supportive and interconnected innovation community (Pinchot & Pinchot, 1996).
- Cross-functional teams that foster close collaboration among engineering, marketing, manufacturing and supply-chain functions (Eppinger & Chitkara, 2006; Gebert, Boerner, & Kearney, 2006).
- An organization structure that breaks down barriers to innovation (flat structure, less bureaucracy, fast decision-making) (Buhler, 2002; Chanal, 2004).
- Managers at all levels that support innovation (Buhler, 2002).
- A reward system that reinforces innovative and entrepreneurial behaviour (Saleh & Wang, 1993).

The organising function includes a second sub-set of activities concerned with growing a supportive and interconnected innovation community (Pinchot & Pinchot, 1996) and the establishment of effective external linkages with technology suppliers, markets and other organisational players (Tidd, et al., 2005). Fayol's controlling function has three sub-sets of activities. They are the development and implementation of suitable innovation processes (Section 2.5 deals with this topic), the application of appropriate innovation tools (Amidon, 1998; Shane & Ulrich, 2004) – the focus of this study, and the identification of appropriate innovation metrics and the overseeing of its subsequent and continued measurement (Adams, Bessant, & Phelps, 2006). The seventh activity area, under the leadership function, is the provision of innovative leadership that provides a strong and significant influence on organisational learning which indirectly affects firm innovation (Aragón-Correa, García-Morales, & Cordón-Pozo, 2007) and furthermore stimulates employees' idea generation and application behaviour (de Jong & Den Hartog, 2007). This approach to viewing the management of innovation is a socio-technical one (Cormican & O'Sullivan, 2004) as it includes people and process, as well as technology related issues.

This research focuses on the controlling function of innovation, in particular on a sub-set of innovation tools and to a lesser degree, on process and metrics. Consideration and discussion of the factors within the other activity areas fall outside the scope of this study, except where specific tool relationships need to be mentioned.

Figure 6: Innovation management – scope of activities



This sub-section identified the various pieces of the innovation management puzzle and pointed out the one piece that is the focus of this study. The purpose of the next section is to obtain a general understanding of how small high technology firms conduct NPD, before focusing on the specialised topic of NPD tools in later sections.

2.4 NPD in Small Firms

There are significant differences between NPD management in small and large firms (Ledwith & O'Dwyer, 2008; Pullen, de Weerd-Nederhof, Groen, Song, & Fisscher, 2009). The purpose of this section is to point out the main differences in how NPD is conducted between small and large firms by focusing on some unique characteristics of small firms in this regard, and identifying the challenges that small firms face. Against this backdrop, it will be more conducive to interpret the findings of the NPD tool research in later chapters.

The NPD literature on SMEs is immature (Wang & Costello, 2009) and scarce as Ledwith and O'Dwyer (2008, p. 41) attested: "The importance of new product development to the survival and success of firms is well supported in the literature; however, few studies have investigated new product development in small to medium-sized enterprises (SMEs)". Noke and Radnor (2009, p. 319) agreed: "Many examples of 'good' NPD practice exist within the literature. However, these examples and the associated determinants of NPD success principally focus on large organisations. In this paper, SMEs are argued as being different in their approach to developing new products [than larger firms]...". So, while relatively little NPD research has been carried out among SMEs (although the last three years have seen an increased interest in this domain), the problem is compounded in the context of this thesis because, among most of the published papers, the term SME mostly refers to international definitions of SMEs that differ significantly in size from New Zealand's definition. For example, the European Union (2003, p. 39) defines SMES as "the category of micro, small and medium-sized enterprises (SMEs) that is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million." As I have stated elsewhere, SMEs in the New Zealand context (which accounts for two thirds of the survey sample of firms in this study) only includes firms with payroll numbers between 1 and 19 FTEs. I therefore conclude that the review of NPD literature on SMEs that follows is largely applicable to firms that are relatively small in world terms, but at the same time significantly larger than the target firms of the current study. Still, a review of this nature is justified as it does provide useful contextual insights into the differences that exist in NPD practices between smaller and larger firms. Such insights are useful because they provide a frame of reference against which NPD factors in small firms can be studied. In this review, I use the terms 'small firms' and 'SMEs' interchangeably.

2.4.1 Factors Distinguishing NPD in SMEs from that in Larger Firms

In a broad overview of management structures in SMEs, (Matzler, Schwarz, Deutinger, and Harms (2008) summarised some general characteristics as an often dominant role of top management (because of the fact that many CEOs have an ownership stake in their ventures) and consequently extensive decision-making power residing with them; flat hierarchies which imply a large span of control; and the tendency to manage in an informal way. Christofol, Delamarre, and Samier (2009) suggested that SMEs have distinctive strengths in that they have strong reactivity to environmental changes; they operate in organisations that are partitioned only slightly – favouring interdisciplinary work; and they have greater access and availability to decision makers than is the case in larger firms. Communication between functional groups tend to be better than in large firms (Ledwith & O'Dwyer, 2008). Shorter lines of communication, relatively informal decision making and more flexibility give SMEs an advantage for rapid innovation over larger companies (Maravelakis, Bilalis, Antoniadis, Jones, & Moustakis, 2006).

In their literature review of small firms and innovation in the UK, Hoffman, Parejo, Bessant, and Perren (1998) found it often hypothesised that SMEs did not innovate in formally recognised ways, and compared to larger firms, they used external linkages to a much greater extent. As small firms often have to rely on external resources or knowledge for product innovation, they employ collaboration as a mechanism to leverage market competitiveness and limitations for product innovation (Sawang & Matthews, 2010). These authors indeed confirmed a positive relationship between external collaborators and product innovation. A couple of studies (Hoffman, et al., 1998; Roper, 1997) found that NPD processes in small firms tend to be informal, but even among those small firms that did employ formal processes, no studies were found that linked NPD process formality (or completeness) with new product success in small firms (Ledwith & O'Dwyer, 2008). SMEs have frequently been found to suffer in the management of their product innovation process through a lack of structure (Maravelakis, et al. (2006) citing Jones, et al. (2001)), often conducting NPD in an ad hoc manner (Millward & Lewis, 2005). Wang and Costello (2009, p. 88) referred to this as an "innovation management gap" that often exists in small firms. This inability to manage innovation is further characterised by insufficient planning, inadequate resources and inattention to design requirements, and ultimately failure to realise the benefits of innovation. Common factors that were often found to cause delays in NPD include poor definition of product requirements, technological uncertainties, and poor management (Owens, 2007). Similar to the NPD process, NPD strategy tends to be implemented with minimum formalisation (Lindman, 2002), but different from NPD process, one study (Terziovski, 2010) confirmed a positive and significant relationship between innovation strategy and SME performance. In an overview of barriers to successful NPD in small manufacturing firms, Millward and Lewis (2005) identified some critical barriers as SMEs typically avoiding formal documented processes; failing to undertake effective competitor analysis; not measuring NPD performance; engaging manufacturing personnel too late in the development process; placing too much emphasis on technology issues (at the expense of marketing and other management issues); and maintaining 'do-it-yourself' and 'just go do it' cultures. In their own case study research, they furthermore identified three generic managerial issues that impinge on the NPD process: (1) the influence of a dominant owner/manager (not acknowledging their personal deficiencies, making a disproportionately high number of key development decisions, acting as sole design authority, being driven by short-term requirements); (2) a focus on time and cost ahead of other key factors (having unrealistic development expectations, allowing short-term considerations to affect decision-making, viewing activities such as iteration or evaluation of alternatives as unnecessary, compromising quality, omitting key development stages such as market research, and showing no interest in learning from development experience); and (3) the failure to understand the importance of product design (treating product design simply as the 'front-end' of the development process, overlooking its strategic importance, and creating inadequate design documentation).

Barnett and Storey (2000) pointed out NPD training as another difference between SMEs and larger firms. Larger firms generally place great emphasis on employee development training through industrial education of new employees and graduates in the form of scholarships, apprenticeships and student placements – in stark contrast with SMEs in general.

2.4.2 NPD Challenges Facing SMEs

Several studies identified challenges distinctive to high technology SMEs that managers face when developing new products. Akgün, et al. (2004) listed such challenges, relative to larger firms, that include greater difficulty in obtaining financing for risky R&D projects, being more unfamiliar with the challenges surrounding the new product (e.g. dealing with new vendors, new markets, rapid or sudden technological changes, shortening of product life cycles, etc.) and employing people who predominantly have technical and manufacturing backgrounds rather than marketing. Small firms often come second to larger firms in recruiting and retaining high caliber technicians and talented people (Wang & Costello, 2009). Christofol, Delamarre, and Samier (2009) cited similar challenges, and added a couple more: limited in-house skills and resources; and a lack of information on the medium- and long-term trends of the environment. Still on the issue of finance, or rather, the lack of it, Storey (1982) described the typical situation where SMEs, at the time of their inception, entered the market as single product or technology-led companies that often lacked the finance to broaden their product range. During those early years, they do not have other products (cash cows) to compensate for a lack of sales and profits (Pullen, et al. (2009) citing Michael & Palandjian (2004)). After having been in business for some years, a major issue for such SMEs is how to survive by maintaining or increasing market share through innovation (Laforet & Tann, 2006).

2.5 FACTORS MODERATING NPD PERFORMANCE

There are many factors that moderate NPD performance, but two in particular - NPD process and innovation strategy - are so closely linked to tool application and use that I find it necessary to include aspects thereof in this study. In fact, both concepts can be seen as tools in their own right according to my operational definition of tools in Section 2.2.2, page 15.

2.5.1 NPD Process

With regard to NPD process (which I define and discuss in Section 2.2.6), plenty of evidence suggests that the use of a repeatable NPD process is related to successful new product outcomes (Cooper & Edgett, 1996; Cooper & Kleinschmidt, 1995; Rochford & Rudelius, 1997). More specifically, the existence of a “high-quality, rigorous new product process” was found to be one of the strongest drivers of profitability (Cooper & Kleinschmidt, 2007, p. 52). Empirical evidence furthermore suggests that the proficiency of process management is an important predictor of NPD performance (Akgün, et al., 2004; Salomo, Weise, & Gemunden, 2007). However, a study of NPD process proficiency falls outside the scope of this research.

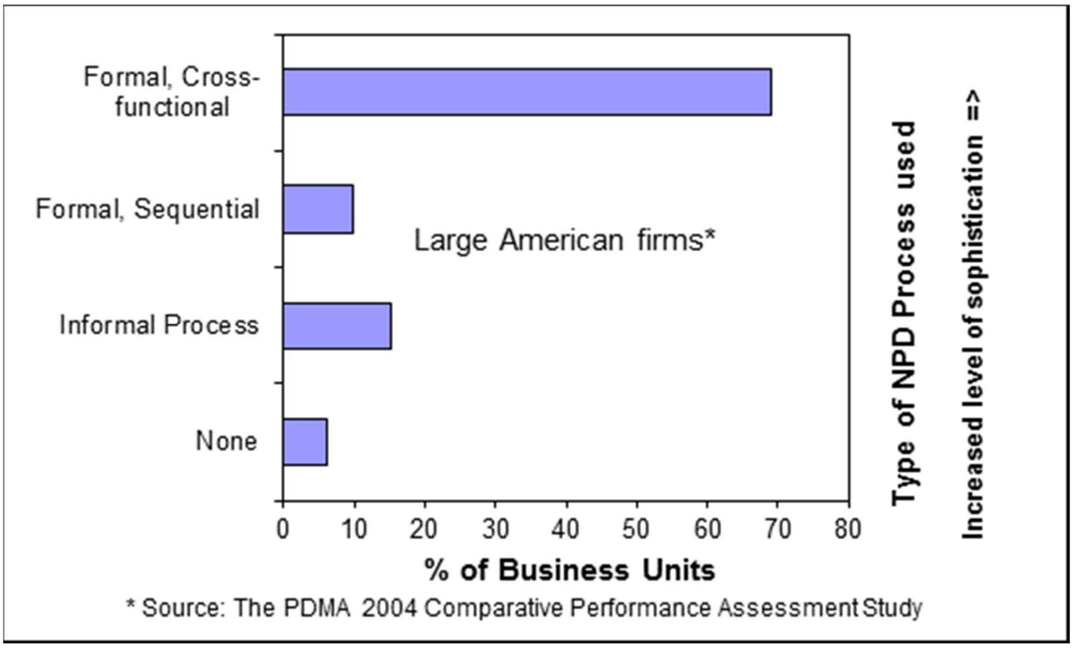
A study among larger firms (Adams, 2004) found that the majority (in excess of 80% - adding the two top bars in Figure 7) of firms have formal NPD processes in place. Adams used the following measurement scale in her study for NPD process:

- No standard approach to new product development (‘None’ in Figure 7)
- While no formally documented process is followed, we follow a clearly understood path of the tasks to be completed in product development (‘Informal process’ in Figure 7)

- We have a formally documented process where one function completes a set of tasks, then passes the results on to the next function, which completes another set of tasks ('Formal, sequential' in Figure 7)
- We have a formally documented process where a cross-functional team completes a set of tasks, management reviews the results and gives the go-ahead for the team to complete the next set of cross-functional tasks ('Formal, cross-functional' in Figure 7)

There is limited data for other countries, but corresponding figures with regard to process formalisation for Sweden (Rundquist & Chibba, 2004) and Malaysia (Al Shalabi & Rundquist, 2009) are 71% and 58% respectively. Around the same time as the American study, though, another survey found that only 27.9% of American businesses reported that their employees understood and supported their NPD processes (Cooper, et al., 2004a). This suggests that the formalised processes probably had a much more limited impact than these businesses would have liked.

Figure 7. Type of NPD process used among American firms



The first identified gap in the literature relates to the process - performance relationship that was found to exist for larger firms. Would this hold true for small firms? As indicated in Section 2.4.1 (p. 37), innovation within small firms is generally done informally. NPD processes, in particular, have been described as being 'ad hoc', without structure, and informal. Another question that remains unanswered, relates to the types of NPD processes (referring to the above categories of NPD processes of Adams (2004)) used by small high technology firms. Given the particular demographic of sample firms in this study, the ratio of firms with formalised/structured NPD processes to firms following informal/unstructured processes is expected to be very low. For those small firms that are more disciplined in their approach to innovation, there is no obvious reason to expect that the observed process – performance relationship for bigger firms does not hold for smaller firms. As there are two aspects to NPD process – process formalisation and process sophistication, I hypothesise two relationships for small high technology firms:

*$H1^{perf}$: The presence of a formalised NPD process is positively associated with NPD performance**

*$H2^{perf}$: The level of NPD process sophistication is positively associated with NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

An investigation of this nature would fill the gap identified by Ledwith and O'Dwyer (2008) that to date no studies could link NPD process formality with NPD success in small firms.

A second gap in the literature is that no research has been carried out among small high technology firms to determine what types of NPD processes they employ.

2.5.2 Innovation Strategy

NPD process is intrinsically linked to innovation strategy, as the latter dictates, amongst other things, the most appropriate process(es) for the firm's context and targets — whether these processes are relatively simple or complex (Dodgson, et al., 2008). Mercer's (Mercer Management Consulting Inc, 1994) comparison of high and low NPD performing firms found that strategy for the NPD programme as a whole was an important differentiator (68% in higher performers and 43% in lower performers). Cooper, et al. (2004b, p. 51), in their comparison of best versus worst performers (of which the average annual sales was USD2.5 billion), empirically observed that the role of NPD in achieving the overall business goals is the "element of an innovation strategy [that] is the most strongly correlated with NPD performance". In this context, NPD performance was gauged at the firm's portfolio level. In simple terms, innovation strategies help firms choose the right innovation projects. Other interrelated elements involved in innovation strategy include a project's 'fit' with overall company strategy, the allocation of available resources, goal setting, and the identification of required innovative capabilities for successfully carrying out a project. The latter aspect includes the outsourcing of activities and licensing in of required intellectual property. Specifically, goal stability throughout the development process has been found to enhance performance significantly (Salomo, et al., 2007).

A review of the literature confirms that the majority of large firms' NPD efforts are guided by some form of innovation strategy as the following research shows: For American firms: 80% (Adams, 2004); for Swedish firms: 73.3% (Rundquist & Chibba, 2004) and Malaysian firms: 76% (Al Shalabi & Rundquist, 2009). As early as 1982, Booz, Allen and Hamilton (1982) reported that 77% of firms they surveyed started their NPD processes with a strategy-developing step for each project.

Since strategy is enacted at different organisational levels, Griffin and Page (1996) argued that as firms start NPD projects for different reasons and use different project strategies, each project's success objectives can be expected to vary (refer to Section 2.3.2 where a distinction is made among six project strategies: new-to-the-world, new-to-the-firm, additions to existing lines, product improvement, product repositioning, and cost reduction). For example, the objectives of incremental NPD projects may simply be to retain current customers or arrest margin erosion, whereas radical NPD projects may have as their objective the penetration of new customer or market segments. Although Griffin and Page (1996) continued to propose sets of most useful measures for each project strategy, a scrutiny of the literature failed to show up any empirical work done in this regard. It is therefore impossible to carry out benchmarking exercises for either large or small firms.

Based on the literature review it appears that it is common for large firms to have innovation strategies in place, and that a relationship exists between innovation strategy and firm performance. Once again, this relationship has been tested for large firms and it is uncertain whether it stands fast for small firms, if it can be assumed that small firms employ innovation strategies at all. Furthermore, NPD performance was measured at the portfolio level (rating projects on average), not at the project level. In addressing these gaps in the literature, I frame the hypothesis in the context of small firms where the focus is on a single NPD project:

> *$H3^{perf}$: The presence of an innovation strategy is positively associated with NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

2.6 NPD TOOL RESEARCH AREAS

Table 6 summarises and relates existing research to the set of eight research areas that I identified in Figure 2 (page 13), with corresponding research questions. A review of the literature follows for each of the eight major areas of tool research. While this study's unit of research is a single NPD project, I include research findings that were carried out at the programme or company levels, as it contributes valuable insights to the overall body of knowledge and provides useful ideas for research at the project level. In cases where I derive hypotheses from the literature that was done at the programme level, I make the required adaptations in line with studying NPD tools at the project level.

Table 6. NPD tool research agenda

Tool focus area / topic	Research Questions
1. Tool application (Adoption & Diffusion) [b, c, f, g, h, i, j, m, n]	1) To what extent do practitioners† use tools or categories of tools? * Adoption of a specific tool by individual firms * Diffusion within an organisation, measured as the number of tools adopted by a firm * Diffusion among a group of organisations, measured as the cumulative number or percentage of firms that adopted an NPD tool
2. Determinants [f, g, i, l, v]	2) What factors determine tool adoption?
3. Obstacles [p]	3) What are the major obstacles to tool adoption?
4. Awareness [a, b, c]	4) To what extent are companies/practitioners† aware (by name, and by content) of the existence of NPD tools?
5. Reasons for use [a, c]	5) Why do practitioners† use tools? How do they select them?
6. Tool Usage [a, c, k, l, o, t, u]	6) How do practitioners† apply tools in practice? 6.1) When applying tools, to what degree of thoroughness do practitioners† follow industrial standard guidelines? 6.2) To what degree do practitioners† adapt tools in order to better meet the requirements of a particular project?
7. Process performance [a, h, m, o] and Product performance [a, h, m, o, s]	7.1) Does the use of NPD tools relate to NPD process performance? 7.2) Does the use of NPD tools relate to product performance?
8. Problems and Shortcomings [c, d, f, k] Usefulness [a, e, f, g, j, l, o]	8.1) What are the major problems practitioners† encounter while working with NPD tools? 8.2) How satisfied are practitioners† with specific tools? (measured as perceived effectiveness or usefulness)

† Practitioners include NPD project managers, cross-functional team members, consultants, and collaborators

a: (Nijssen & Lieshout, 1995) b: (Mahajan & Wind, 1992) c: (Nijssen & Frambach, 1998)
d: (Dodgson, Gann, & Salter, 2005) e: (Farris, Van Aken, Letens, Ellis, & Boyland, 2007)
f: (Chai & Xin, 2006) g: (Thia, et al., 2005) h: (Yeh, et al., 2008a)
i: (Nijssen & Frambach, 2000) k: (McQuater, et al., 1995)
l: (Tidd & Bodley, 2002) m: (Maylor, 2001) n: (Adams, 2004)
o: (Farris, et al., 2003) p: (Thomke, 2006) s: (Kleinschmidt, 1994)
t: (Knott, 2006) u: (Knott, 2008) v: (Westphal, Gulati, & Shortell, 1997)

2.6.1 Adoption and Diffusion of Tools

Tool application has two aspects: adoption and diffusion (Nijssen & Frambach, 2000). Adoption refers to a firm's decision to either use or not use a particular tool in its NPD process. In this research, adoption specifically relates to the NPD team's decision to use a particular tool in a particular NPD project. Tool diffusion can be studied from the perspective of a single firm, or from the perspective of a group of firms collectively. In the former case, the appropriate terminology is tool diffusion within a firm, which gives an indication of the cumulative number of tools that a particular firm has adopted (in the case of this research, for use in a particular NPD project). Secondly, tool diffusion among firms measures the number or percentage of firms that have adopted a particular tool (Chai & Xin, 2006).

Tool diffusion within firms

Research in the United States (Mahajan & Wind, 1992) found the use of tools and techniques in support of the NPD process among Fortune 500 firms relatively low, although large differences in penetration existed between tools. The period 1991 to 2000 was reported to experience a remarkable increase in the use of NPD tools and techniques by individual firms in the surveyed sample, but growth seems to have slowed down at the time of the study, resulting in some degree of saturation. Almost a decade later Nijssen and Frambach (2000) found that the current number of tools used among the 70 Dutch companies in their research sample was approximately three per company (average diffusion within a company), bearing in mind they only tested for 11 tools. Maylor's (2001) English study of 21 tools, however, found the corresponding figure to be 11.6, which is very close to the 11.4 obtained for management tools, as measured at approximately the same time by Rigby (2001b). Apart from these studies, I could find no others that reported on specific diffusion-within-firm rates.

When studying tool diffusion patterns within firms, past research investigated the effects of three potential moderating variables. The first relates to the degree of novelty of NPD projects. An empirical study conducted among bigger firms (Tidd & Bodley, 2002, p. 135) found that, for the firms in their sample, "the majority of the methods and techniques reviewed are equally applicable to high and low novelty projects" (in this context low novelty equates to NPD projects of an incremental innovation nature, and high novelty to more radical-type projects). Intuitively, this makes sense, as one would expect that the more radical type of projects, by nature of their higher levels of associated uncertainty than in the case of incremental innovation projects, would involve the use of more tools (higher tool diffusion rates within firms/projects) to alleviate risks and help overcome bigger development challenges. To test this assumption, I formulate the null hypothesis as:

H1^{adopt}: Tool diffusion rates within projects are not dependent on the type of innovation project

McGuire (1973) indirectly suggested a second potential moderating variable for tool diffusion within firms when he illustrated different NPD flows for consumer and industrial product companies. In line with this idea, Nijssen and Lieshout (1995) found through expert interviews and focus groups that NPD research should control for the differences between consumer goods and industrial goods companies (business to business). They concluded that (large) industrial companies conduct NPD in a different way compared with (large) consumer goods companies. I wanted to test whether these points of view extended to the application and use of NPD tools in projects within small high technology firms and henceforth I formulate the null hypothesis as:

H2^{adopt}: Tool diffusion rates within industrial NPD projects are not different from tool diffusion rates within consumer NPD projects

A third potential moderating variable cited in literature is the type of NPD process employed (see Sections 2.2.6 and 2.5.1 for an overview of NPD process). Thia, Chai, Bauly and Xin (2005) suggested that because different industries adopt different NPD processes, it seems logical that the type of NPD process might indirectly affect the choice of tools and the number of tools adopted. While Adams' findings provide frequency distributions for types of process adoption among large firms, neither hers nor other scholars' studies have tested the proposed relationship between process type and tool adoption statistically. To test this proposition, I define the null hypothesis as:

H3^{adopt}: Tool diffusion rates within projects are not dependent on the type of NPD process

Tool diffusion among firms

Many more studies, however, reported on specific tool diffusion among firms (Adams, 2004; Chai & Xin, 2006; Farris, et al., 2003; Nijssen & Lieshout, 1995; Thia, et al., 2005; Tidd & Bodley, 2002; Yeh, et al., 2008a). I found there was very little consistency among these studies in the specific tools that they included, and the number of tools that they measured (ranging from six to 45 – see Table 3, p.22). As I observed in Section 2.2.5, individual research efforts do not address the full scope of tools that practitioners can use in NPD. As a result, the adoption rates have not been measured for many legitimate NPD tools, which is clearly a gap in the literature. Among those tools studied, findings indicate that some tools such as ‘brainstorming’, ‘prototyping’ and ‘project management’ had high adoption rates of 70% and higher, while others such as ‘synectics’, ‘design of experiment’, ‘knowledge management’ and ‘quality function deployment’ had adoption rates of less than 20%. Clearly, some tools are much more popular than others are. Based on my own research findings, I provide a detailed comparison of tool diffusion rates among firms with the work of others later in this thesis (see Table 17, p. 112).

Another gap in the literature is the absence of any research on how firms or NPD practitioners within firms select tools for use in their projects. As such very little is known about the tool adoption processes within firms of any size.

2.6.2 Tool Determinants

Tool determinants are those factors that determine tool adoption within the organisation. Nijssen and Frambach (2000) suggested that, because of empirical findings that suggest a link between the use of NPD tools and companies’ financial performance, top management may want to stimulate the adoption and use of tools. Table 7 provides a summary of the factors that have been researched with regard to the propensity of large organisations to adopt NPD tools. It is important to consider these factors as most are under direct management control, and can therefore be manipulated to achieve the desired results. There are discrepancies in two of the factors of past research: (1) a marginal discrepancy in top-management support in terms of the strength of the positive relation, and (2) the effect of firm size – one study found a significant positive relation with tool adoption while another study found none.

Several of the potential determinants listed here may not be entirely appropriate for very-small-firm studies (such as the current study), though. The ‘level of interdepartmental communication’ and ‘the level of involvement of all the firm’s departments’ are good examples. In Section 2.4.1 (p. 37) it was shown that communication between functional groups tend to be better than in large firms, possibly because of shorter lines of communication. Thus, despite apparent good levels of communication in small firms, in the current study it might be impossible for some participants to answer such questions because a large portion of participating firms is not expected to have departments or different functional groups. Such participants to this study may therefore compensate in how they answer the question by simply referring to the level of communication among members of the core team that makes up the firm’s sole ‘department’. Because of the said good communication characteristic of small firms, the expectation is for this determinant to hold as it does for larger firms. A similar argument applies to the 'level of involvement of all the firm's departments' where simple perceptual measures of situations that are not really applicable, cannot be seen to be very reliable, and certainly susceptible to common-rater bias.

Another example is 'top management's involvement in the process'. Because of the very small size of firms in this study, 'top management' could typically be what the literature refers to as the 'dominant owner/manager/CEO' that is perhaps joined by a handful of business partners. Top management thus represents either a single person or at best a very small team who are all intimately involved in the business activities of NPD as they are the only people in the firm. The point I want to make here is that the term 'top management' may mean different things to different sized companies. Still, it is worth testing for this relationship as the findings may confirm the negative influence of the dominant owner manager on the NPD process, as postulated and explained in Section 2.4.1 by Millward and Lewis (2005), and thereby contradicting the significant positive relationship for large firms.

Inclusion of the determinant 'former use of NPD tools prior to the current project' may also be ambiguous as it is anticipated that a huge portion of the firms participating in the study will be new technology start-ups that will be running their first NPD projects and therefore may not have used tools before. On the other hand, some participants may respond in the affirmative to this question as they may interpret it as inclusive to situations where they have used tools in projects outside the current environment, perhaps in previous employment situations with other firms. Consequently, it is difficult to call whether this relationship will hold as it does for larger firms.

As discussed earlier, small firms operate very informally and tend not to have formalised innovation strategies in place. Still, because of the possibility for firms having unwritten NPD strategies, the determinant 'the NPD strategy's focus is on turning out many new products' is included in this study as a potential determinant. However, it is not expected to be a significant determinant for small firms as most participating firms are expected to have been recent start-ups of which the main aim was to first become successful with a specific opportunity that may have involved only a single product or technology.

Two large-firm determinants relate to the number of people involved in NPD: firm size, and team size. It is uncertain if the size-construct will turn out to be a determinant of tool adoption for small firms, as past research found contradicting results among large firms (Chai & Xin, 2006; Nijssen & Frambach, 2000). Logic dictates that the size-factor will be a significant determinant of tool adoption because the more people that are involved in a project the bigger are the chance that any member may introduce a new tool or tools into the project.

Be it as it may, I included all the large-firm determinants in this study as their findings may point to interesting differences between small and large firms. To minimise incidents of common-rater bias and to avoid situations where rating a question would be inappropriate, I added a sixth scale "Not applicable" to the usual 5-point Likert-type scale.

Table 7: Tool determinants

Significant positive relation	The level of interdepartmental communication[1] The number of stages in the NPD process[1] The company's innovation/NPD strategy[1] The firm's prior adoption of tools and techniques[1] †Top-down management support[2, 3] *Firm size[3]
Marginally significant positive relation	The number of departments involved in NPD[1] †The influence of top management[1] Team size[1]
No identified relation	*Firm size[1]

Notes

1: (Nijssen & Frambach, 2000), research done on industrial companies

2: (Rigby, 2001b), research done on management tools

3: (Chai & Xin, 2006), only surveyed 8 tools

*†: Discrepancies

The identified determinants of tool adoption all relate to studies conducted in large firms at the general programme level; hence, I formulate the following sets of hypotheses for testing the relationships within small high technology firms:

$H1^{det}$: The level of communication between departments is positively associated with the level of tool adoption in projects

$H2^{det}$: Former NPD tool users are more likely to adopt new NPD tools in projects

$H3^{det}$: The level of top management involvement with the NPD process is positively associated with the level of tool adoption in projects

$H4^{det}$: A higher level of involvement of all the firm's departments is positively associated with the level of tool adoption in projects

H5^{det}: An NPD strategy focusing more on turning out many new products is positively associated with the level of tool adoption in projects

H6a^{det}: Firm size, with regard to the number of full-time staff, is positively associated with the adoption of NPD tools in projects

H6b^{det}: Firm size, with regard to the firm's annual turnover, is positively associated with the adoption/application of NPD tools in projects

H7^{det}: The size of the NPD team is positively associated with the level of tool adoption in projects

H8^{det}: The number of stages within the NPD process is positively associated with the level of tool adoption in projects

2.6.3 Obstacles to Tool Use

It is important for managers to know what the most common organisational and personal impediments to tool adoption are, so they can find ways to overcome them. Congruent with organisational change theory, Thomke (2006) found that tool users often resist embracing new tools because they fear a disruption of the established and proven ways of doing things. Rigby (1993) reported that beleaguered managers who were struggling to survive in unforgiving economies during the eighties were buying up tools in unprecedented numbers. They did so to demonstrate that they were not afraid to adapt to a world characterised by rapid change. Consequently, many employees became 'groggy' from trying to absorb and implement what Rigby referred to as a succession of management tools. From these observations, Rigby (1993, p. 9) deduced his 'New Tool Rule': "The people who get a high from buying all the latest tools are the least likely to use them to do hard work." He also calls this syndrome 'toolism'.

Thomke's research (2006) into the use of state-of-the-art innovation tools in the global auto industry revealed a number of common obstacles. For example, a company's existing processes, organisational structure, management and culture, have the potential to create bottlenecks that prevent the introduction of new leading-edge tools to result in exponential leaps in performance. He used the analogy of driving a Ferrari to work amidst huge congestion, observing that it would take somebody in an ordinary vehicle the same amount of time. Unless such tools are accompanied by appropriate change in mentioned areas, their potential will be inhibited. Other commonly observed pitfalls by Thomke include:

- Adding (instead of minimising) interfaces: This happens when new tools achieve some positive outcomes for existing problems, but at the same time create new problems in other areas, both functional and organisational.
- Changing tools, but not people's behaviour: When tool users find it hard to let go of tried and tested ways of doing things, the introduction and implementation of new tools will suffer. The condition within organisations where the rate of technological change exceeds that of behavioural change should be avoided.

Other identified obstacles to tool use include:

- Potential users being unaware of the existence of tools (Feldman & Page, 1984). Nijssen and Lieshout (1995) suggest it is the job of universities, polytechnics and consulting firms to fill this gap;
- Firms not having ascertained the effectiveness of various NPD tools (Yeh, et al., 2008a);
- R&D engineers lacking proficiency in the use of tools, or not knowing which tools are appropriate for use at each stage of the process (Yeh, et al., 2008a);
- Unsupportive organisational cultures (Feldman & Page, 1984). Brady, et al. (1997) stresses the importance of developing the right conditions and capabilities for tools to work;
- Limited faith of managers in the usefulness of these tools (Verhage, Waalewijn, & van Weele, 1981);
- The lack of involvement of market research companies to assist in solving NPD-related problems (Thia, et al., 2005);
- A view held by some that NPD tools are considered to have a more academic than practical role, because of a lack of tool awareness and motivation among practitioners to use tools in helping their companies survive (Hidalgo & Albors, 2008).

The literature review revealed numerous obstacles to tool adoption in large firms, but is uncertain whether all of them apply to small firms, and if managers and NPD teams in small firms experience problems that are unique to their contingency.

2.6.4 Tool Awareness and Familiarity

Notargiacomo (2009) believed it is the job of innovators and product developers to know when to use a tool, as well as whether they have the expertise to use it themselves or if they need to call in someone with greater expertise to guide them. This, of course, only makes sense if one assumes that practitioners are firstly aware of tools, and secondly, that they have a certain level of knowledge and competency in using it - referred to as tool familiarity.

Tool familiarity reflects the extent to which users are aware - by name and by content - of the existence of specific NPD tools. There appears to be a subtle difference between tool awareness and familiarity. A user is either aware of a tool's existence, or not. If a user is aware of a tool, the degree of awareness, or familiarity, can range from 'by name only' at one extreme to 'very familiar' at the other extreme. In between these extremes, users obviously differ from one another with regard to the 'amount of content' of a particular tool they are familiar with.

Probably the first study of this type by Mahajan and Wind (1992) found that respondents in the Fortune 500 firms could not provide an adequate insight into the problem of awareness and knowledge when confronted with only the names of NPD tools. Singaporean research (Thia, et al., 2005, p. 411) stated "... it is surprising that some of the tools investigated in this research are unknown to some of the industrialists". Nijssen and Lieshout (1995) came to the same conclusion when interviewing focus group members in the Netherlands. Their survey results of 11 tools found the average awareness of the respondents with NPD tools by name at only 30%. On the positive side, once the tools were explained, these people were able to recognise them and familiarity increased to 57%. Three tools in particular - 'Delphi method', 'synectics', and 'limited roll-out' - only achieved 18%, 28%, and 29% familiarity after explanation, respectively. European studies that focussed on the Fuzzy Front End (Nijssen & Frambach, 2000) found that apart from 'brainstorming' there was little awareness of idea generation tools. Very recent research indicated that the awareness problem is alive and well (Hidalgo & Albors, 2008). It shows that consultancy firms and business schools generally believe that most firms are not aware of the existence of NPD tools, that tools are not readily identifiable, and are inaccessible.

In conclusion, a review of the literature indicates a high occurrence of NPD practitioners in large firms who are not overly familiar with NPD tools. From Section 2.4.1 (p. 37) a number of NPD-in-small-firm characteristics indicate that the tool-familiarity situation is likely to be worse than in larger firms: (1) the 'do-it-yourself' culture where practitioners devise custom-made tools instead of reverting to familiar, well-proven solutions; (2) less devotion of smaller firms to employee development training – thus denying employees the opportunity to become aware of new tools and getting them adequately trained; and (3) the tendency among small firms to take shortcuts and omitting key development stages that could have alerted team members of new and appropriate tools to use. This proposition remains to be tested for practitioners in small firms.

2.6.5 Reasons for Tool Use

At a very basic level, practitioners use tools for two reasons. The first is to help them become effective (Koen, et al., 2002), achieving something that they would otherwise not be able to do. Without having developed an alpha prototype, for example, one would not be able to prove technical feasibility of an advanced technological concept. The second purpose of tools has to do with efficiency: "… (tools) hold the promise of faster, better, cheaper" (Thomke, 2006, p. 24). More advanced tools would allow one to complete a job faster and probably at less cost than with less-advanced tools. Obviously, 'computer-aided design' would enable a design engineer to be much more efficient in doing the design of a product rather than using manual draughting tools. Some tools are indispensable in achieving certain outcomes (effectiveness), while others simply help achieve better results (efficiency).

In a very general sense, evidence suggests that organisations revert to using tools for the following reasons:

- Tools help identify problems and improve on or predict new product success (cited as first and second reasons by both Nijssen and Lieshout (1995) and Mahajan and Wind (1992);
- Tools facilitate positive change and improvements (McQuater, et al., 1995);
- Tools enhance a firm's NPD efforts (Nijssen & Lieshout, 1995);
- Tools affect product performance enhancements such as time to market, product cost and product quality (Maylor, 2001);
- Tools can be used to improve management's decision quality at different stages of the NPD process (Schelker, 1976).

Recent research (Hidalgo & Albors, 2008) of 426 firms within the 15 Member States of the European Union that actually implement NPD tools, found the reasons for adoption as follows:

- Increasing flexibility and efficiency (86%);
- Managing knowledge effectively (76%);

- Improving productivity and time-to-market (73%);
- Gathering on-line marketing information (69%);
- Facilitating teamwork (67%);
- Integrating different sources of customer information (66%);
- Reducing costs by using IT-based solutions (65%);
- Eliminating redundant processes (64%).

Despite these positives, the mere use of tools cannot provide any guarantee of success (Cooper & Kleinschmidt, 1986).

In summary, there appear to be three major motivational categories why practitioners use tools, shown in Table 8. When selecting a tool or set of tools, Brown (1997) and Farrukh, et al. (1999) advised practitioners to use ones that are simple in concept and use; flexible; not mechanistic or prescriptive; capable of integrating with other tools, processes and systems; result in quantifiable improvement; and support communication and buy-in. In reality, though, very few tools will exhibit all of these positive traits and it would be fruitless for users to search for tools whose application is free from unwanted effects (Knott, 2008).

Table 8. Main reasons why practitioners use tools

NPD Process		Product	Management
Efficiency	Effectiveness		
Increase productivity Reduce time-to-market Reduce project cost Eliminate redundant processes	Identify and solve problems Facilitate change (carry out activities) Manage knowledge Research the market Manage information	Reduce product cost Ensure quality Improve performance	Make quality decisions Facilitate teamwork Support communication Predict success

As is obvious from Table 8, past research (which focused on large firms) offered many reasons why practitioners use tools, but the reasons given are normally too broad to be of any use in specific situations, e.g. tools facilitate change and positive improvements. These studies also treated tools as a single concept, failing to indicate which categories of tools were used for specific reasons, which further reduced the interpretation and usefulness of reasons given why tools were used. An equivalent metaphor would be stating that people use vehicles because they are good for transporting cargo, while a better statement would have been to indicate trucks for this purpose because of their large freight capability. The current study aims to close this gap by identifying categories of tools of which their use is appropriate at specific stages in a typical development project, determined by the unique needs of team members within a particular stage, and even during the evolutionary stages of a new technology start-up firm for which growth is dependent on initiating and launching successive NPD projects.

2.6.6 Tool Usage

Although standard dictionaries tend not to distinguish between the terms 'use' [noun or verb] and 'usage' [noun], I do so as there is a subtle difference between these words (Wordpress, 2005) that have important implications for my study. Therefore, in the context of NPD, the word 'use' [verb] means to employ a tool for a given purpose; to put it into action; to apply it. Tool 'usage' [noun], on the other hand, refers to the way that a tool is actually used in practice. It could be that a tool developer provides a set of guidelines or use(r) instructions for a particular tool, but that practitioners, when 'using' [verb] it may deviate from this for a variety of reasons. Thus, actual practitioner usage [noun] may differ from the developer's 'prescribed use' [noun].

Therefore, research into tool usage aims at gaining an understanding of how tools are actually used in practice. Nijssen and Lieshout (1995) reported more than a decade ago that little was known in this area, and since then not a great deal of new information has emerged.

Flexibility

As most of the NPD tools have been developed for specific purposes, for example, problem solving, decision making, or information management, one would expect to see a concentration of tool use at those stages of the NPD process at which the different methods are actually aimed. Nijssen and Lieshout (1995) found this indeed to be the case, but also observed tools being used at other stages. This was true for more than 25% of the 11 tools that they investigated, leaving them with the conclusion that different tools are not used in a focused manner. Mahajan and Wind (1992) also observed that managers select and apply tools at different stages of the NPD process as they see fit. More recent research (Yeh, et al., 2008a) that tracked 26 tools across seven process stages came to a similar conclusion. It found that tools such as 'cross-functional teams', 'brainstorming', and 'knowledge management' are used in most if not all of the stages.

With regard to the NPD process, it appears that many firms do not consider it a highly delineated or neatly, sequential staged activity (Nijssen & Frambach, 2000). Consequently, many tools and techniques were used with a high degree of flexibility, often in an unfocused way to solve problems beyond those they were actually designed for.

While there seems to be consensus among past research that practitioners generally use tools in a very flexible manner, it is not clear if some tools or categories of tools are not used in this way. Thus the questions remain: Which tools are used in a flexible manner and which not? Why are some tools used in an inflexible manner while in other cases practitioners have the freedom to use tools as they see fit?

Thoroughness of use

Another important aspect of tool usage, is the degree of thoroughness to which industrial standard guidelines are followed. The research of Chai and Xin (2006) was the only research that made any attempt to determine this, albeit for a small number of tools in their survey (eight tools). 'FMEA' was the tool most thoroughly used (3.97), while the thoroughness of the seven remaining tools was centered between 3 and 4 on a 5-point Likert-type scale (5 representing a very high degree of thoroughness). Clearly, this topic is under-researched. Questions that are currently unanswered include: 1) Which tools are most thoroughly used, and which tools least? 2) Why don't practitioners use tools thoroughly? 3) Would practitioners be inclined to use tools less thoroughly in incremental innovation projects than in radical innovation projects because the latter type projects are more complex? 4) Is there a relationship between thoroughness of use and practitioners' perceptions of how useful tools are? 5) Is there a relationship between thoroughness of tool use and NPD performance? 6) Would practitioners be inclined to use those tools with which they are more familiar than others, more thoroughly? Questions three to six lend themselves ideally for hypothesis testing; hence I define the following hypotheses respectively:

> *$H1^{thor}$: Thoroughness levels of tool application are independent of project type/complexity*
>
> *$H2^{useful}$: The thoroughness levels of tool application are not associated with managers' perceptions of tool usefulness*
>
> *$H4^{perf}$: Higher levels of thoroughness in tool usage are not associated with improved NPD performance**
>
> *$H2^{thor}$: There are no differences among the observed means in thoroughness of tool use at different levels of tool familiarity*

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

Adaptation

Knott (2008) found instances where users merely used strategy tools as a source of inspiration without utilising them fully. Tools were sometimes adapted and even (re)invented to better suit particular circumstances. He also found evidence of users taking components from different tools and integrating them into custom applications to suit pre-existing needs. Another study (Nijssen & Frambach, 1998) found that 38% of the market research companies in the sample made extensive adjustments to the NPD tools they were using, whereas another 38% reported they had made an average number of improvements, which included both implementation and tool-content. Topping the list of improvements concerned some kind of standardisation, i.e. making the tool more user-friendly, and customising tools for specific or complex markets. The adaptation and re-invention of tools are not unique to the strategy and NPD fields. Lozeau, et al. (2002) found that, in the broader context of management tools, the reconstruction of tools, or 'corruption of tools' as they refer to it, is quite common in industry. This practice should not be viewed in a negative way. Jarzabkowski and Wilson (2006) actually recommended users to use their experience and inventiveness to adapt existing tools and implement locally tailored solutions. Knott (2008, p. 28) echoed this sentiment in saying "tools must be adapted for each use to obtain the best outcome". Ulrich and Eppinger (2008) argued along the same vein that despite their structured nature, tools are not intended to be applied blindly and recommended teams to adapt and modify tools to meet their own needs and to reflect their institutional environments. On the downside of adaptation, Rahim and Baksh (2003b) warned that individual design engineers often have their own method of applying design tools, which can create undesirable variation in the design process and possible complications in manufacturing.

It is evident from the existing literature that tool adaptation is a common practice, but what is lacking is an empirical study of the various manifestations of tool adaptation. Are practitioners always achieving better outcomes from the adaptations they make, and do they experience any problems because of these adaptations? The case study research of this thesis addresses these and related questions in Section 7.5 (p. 231).

Modes of tool application

Knott (2006) furthermore proposed five generic modes of tool application on the basis that strategy tools need to be used differently according to the problem needs. As Knott derived his typology of tool applications specifically for strategy tools, it may not be fully transferable to

NPD tools. Still, as there is some overlap between tools in the two disciplines, it is worth mentioning the five generic modes of tool application here (see Table 9) and providing some parallel ideas and examples without making an attempt to derive a similar typology for NPD tools, or testing its validity. Obviously this typology has not been tested for NPD tools and as such it offers an opportunity for future research.

Table 9. Knott's (2006) five generic modes of strategy tool application

Mode descriptions	**Strategy tool examples**	**NPD tool examples***
Analytic: Looks in detail at a specified aspect of the problem and seeks to generate specific output using a defined method. Tool centred.	BCG Growth-Share Matrix, real options analysis, 5-Force model (Porter)	Focus group, TRIZ, brainstorming, 5-Force model (Porter)
Dynamic: Focuses on the drivers of the evolution of a firm or its environment. Generates working assumptions for future conditions. Deals with uncertainties, involves a degree of prediction.	Industry life cycle, strategic intent, dynamic capabilities framework	Product life cycle, business case, sales forecast, marketing plan
Metaphorical: Used to inspire fresh thinking about a situation and possible responses. Used in unusual conditions where analytical understanding may not be possible.	Shackleton leadership stories/books; Sun Szu; other military/historical metaphors	Metaphors (idea generation); inventive analogical transfers; La Salle matrix
Facilitative: Aids the strategy activity by fostering creativity and structuring communication. Future oriented, produce dynamic output. Outcomes are driven by the perspectives held by participants at the time	SWOT, Delphi, Scenario planning	Delphi, scenario planning, decision screens, design reviews, stage-gates
Interventionist: Using ideas as a blueprint for action rather than simply as an input to decision making. Substantial commitment of people and funds, has organisational wide implications.	Balanced scorecard, TQM, benchmarking	CAD, prototyping, DfX, change control system, EDMS

* added by researcher for the purpose of this study

2.6.7 Tool Relation to NPD Performance

NPD Performance measures

Since the mid-90s, performance measurement of NPD activities has gained increased prominence among practitioners because the effectiveness and efficiency of these activities not only determine a firm's competitive advantage, but its very survival (Loch, Stein, & Terweisch, 1996; Utterback, 1994). Successful performance measurement enables firms, among others, to communicate NPD objectives, define corrective actions, guide the allocation of resources, and identify opportunities for continuous improvement (Godener & Soderquist, 2004). However, achieving positive NPD results is no easy feat, as is evident from Cooper and Edgett's (2005) North American benchmarking studies:

- Only one product concept out of seven becomes a new product winner;
- 44% of business' NPD projects fail to achieve their profit targets;
- 32% of businesses rate their NPD speed and efficiency as 'very poor';
- Only 51% of projects are launched on schedule.

Much research has been carried out over the past two decades in an attempt to identify suitable performance measures, or even better, to design all-encompassing Performance Management Systems (PMS) for research and development (R&D) and NPD (Chiesa, Frattini, Lazzarotti, & Manzini, 2009; Godener & Soderquist, 2004; Griffin, 1997a; Griffin & Page, 1996; Kleinschmidt, 1994; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995; Rogers, Ghauri, & Pawar, 2005; Ulrich & Eppinger, 2008; Yeh, et al., 2008b). Other research focused on benchmarking the frequency of use of different performance measures in specific industries (Cooper, et al., 2004a; Griffin & Page, 1996; Hertenstein & Platt, 2000). This work is a useful guide to managers for directing performance measurements within their own companies. Interestingly though, several studies have found that despite its importance many firms do not measure NPD performance explicitly (Cooper & Edgett, 2005; Hertenstein & Platt, 2000). In addition, I found that despite the availability of numerous performance measures suggested by academics, very few have followed this up with actual measurements. Section 4.4.2 (p. 73) elaborates on the choice of performance measures for this study.

Impact of individual tools on NPD performance

Only one study did work in this area, that of Yeh et al. (2008a) who studied the impact of 26 tools on individual performance indicators among large Taiwanese firms. They found that tools such as ‘project management’, ‘design of experiment’, ‘FMEA/DFMEA’, ‘benchmarking’, ‘brainstorming’ and ‘supplier design involvement’ had significant impacts on individual process and process outcome (product) performance indicators. While the authors claim that their findings can provide useful guidance to firms that wish to improve their performance in particular areas, the 26 tools that formed part of this study only represent the areas of engineering & design and problem solving. This study does not include any tools from the other ten perspectives (see Sections 2.2.5 and 2.2.6), and is therefore of limited use. To overcome this limitation when testing for tool relation to NPD performance, I define the null hypothesis as:

> *$H5xy^{perf}$: The application of tool x in tool category y is not associated with NPD performance**
>
> *Where tool x represents one of several chosen tools in each of the 12 categories of tools (y = 1 to 12) defined in Sections* 2.2.5 and 2.2.6

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

Relationship between tool adoption within projects and NPD performance

Maylor’s (2001) is the only study that investigated the impact of tool adoption on two broad categories of NPD performance - process and product - each consisting of various performance measures. In his study of 21 mainly engineering and design tools among 46 large manufacturing companies, he used cluster analysis to generate three groups of firms according to their overall level of usage of tools: low, moderate and high tool users. His findings indicated only limited support for higher levels of tool adoption that result in improved performance, for example in the areas of time to market, product cost, and product quality, but not in most other areas. Several gaps in the literature are apparent: (1) the small number of tools studied (21 in Maylor’s case); (2) tools from only one perspective - engineering and design - were included in the study; and (3) the study was done among large high technology firms. To overcome these shortcomings, the current study includes no fewer than 76 carefully selected tools across 12 perspectives (Figure 5, p. 26) among small high technology firms (p. 137). A review of factors that distinguish NPD in SMEs from that in larger firms (Section 2.4.1, p. 37) does not point to any obvious factors that would suggest the findings for small firms would be drastically different from those of Maylor’s (2001). However, simple logic would suggest that by using more tools in a project, the project would be more successful, especially when taking into account the proven associations between individual tools and NPD performance. To test this proposition I define the null hypothesis as:

*H6^{perf}: The level of tool adoption within projects is not associated with NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

Maylor (2001) furthermore investigated whether individual tools are exclusively used by high, moderate or low tool users and found that 66% of the 21 tools in his study belonged exclusively to one of the three identified clusters. As there is no evidence from past research among small firms or any obvious circumstantial factors to suggest a different outcome from Maylor's (2001) for small high technology firms, this relationship remains to be tested for small firms. I therefore define the null hypothesis as:

H4^{adopt}: The use of an individual tool is independent of the cluster membership*

** Assuming it is possible to derive different clusters of tool users, in terms of the average number of tools adopted, in the current study*

2.6.8 Users' Experiences with Tools

Before looking at specific tool user experiences, or tool user experiences in general, it is important not to forget that "the value of a tool is tied to its suitability for use on a given problem and the skill of the person using it" (Notargiacomo, 2009, p. 5). This implies that when a user reports dissatisfaction with a particular tool, the real reason for dissatisfaction could be because the tool was used for a purpose for which it was not designed, or used by a person who was not suitably trained in using the tool. In both cases, tool usage may not result in achieving the desired outcome even though others may have used it very successfully in different contexts.

Companies in many industries have invested billions of dollars on innovation tools in the expectation that these tools will lead to huge leaps in performance, reduce costs and somehow foster innovation, just to be hugely disappointed in the end (Thomke, 2006). In a 2001 survey of 50 projects and 25 firms, Tidd and Bodley (2002) examined the use and usefulness of a range of formal tools and techniques available to support the NPD process. Somewhat surprisingly the results show that many tools rated as useful are not commonly used, and conversely some tools in common use are considered to have relatively lower levels of usefulness - although, with the exception of a few tools, most are rated above 3.5 on a scale of 1 (not useful) to 5 (extremely useful). A separate survey of software tools aimed at enabling the web-based management of innovation within NPD, also shows that the most useful tools, such as 'data mining', are not the most highly used (Farris, et al., 2007).

The main findings of Tidd and Bodley's (2002) research were that, in terms of usefulness, 'focus groups', 'partnering customers' and 'lead users', and 'prototyping' are all considered to be more effective for high novelty projects, and 'segmentation' least useful. 'Cross-functional development teams' are commonplace for all types of project, but are significantly more effective for the high novelty cases.

Research conducted in Taiwan (Yeh, et al., 2008a) generally showed lesser levels of satisfaction than those of Tidd and Bodley. Only three out of 26 tools surveyed achieved ratings above 3.5. They are 'CAD/CAM/CAE' (4.14), 'specific design software' (3.63), and 'Project Management' (3.60). More than half the tools achieved ratings below three, which indicated relatively low levels of satisfaction. The last three in these rankings were 'TRIZ' (2.06), 'Taguchi Method' (2.29), and 'DFX' (2.37).

European studies that focussed on the use of idea generation tools in the Fuzzy Front End (Buijs, 1984; Geschka, 1978, 1983; Holt, 1987), found that those who did use them were not overly impressed, apart perhaps from 'brainstorming', and rated their performance as average. Schelker's earlier investigation (1976) among 90 small and large Swiss companies found a reasonable use of tools and satisfaction in the areas of analysis and forecasting, idea generation and selection, and control and planning. Several decades later Nijssen and Lieshout (1995) found that most users were very satisfied, in particular with 'QFD', 'focus group' and 'morphological analysis'. Similar findings were obtained by Nijssen and Frambach (2000) who reported a high level of user satisfaction for most techniques. Most web-enabled innovation software rated between three and four on a 5-point Likert-scale, indicating overall satisfaction with these tools (Farris, et al., 2003).

Another measure of tool satisfaction is the degree of user-friendliness (Chai & Xin, 2006), of which two fundamental aspects are 'ease-of-use' and 'ease-of-learning'. It followed that tools with higher levels of user-friendliness had higher levels of application in industry.

Rigby's research (1994) on management tools suggested that none of the tools he investigated should be summarily dismissed as being useless. Evidence pointed to worthwhile contributions from each tool given the right circumstances for its use. His findings also indicated that tools do appear to be helpful if the right ones are chosen at the right time and are implemented in the right way. For this to happen requires a sophisticated understanding of the usage of tools, the strengths and weaknesses of each tool, and the keys to successful implementation.

Notargiacomo (2009, p. 5) believed that the value of a tool is tied to its suitability for use on a given problem and the skill of the person using it. “Just as a handsaw has its limitations within woodworking, the tools in our new product development toolbox have limitations as well. But in the right situation, used in the proper way, they can be very effective.”

Tool Limitations

Notargiacomo (2009) stated that every tool in the proverbial ‘NPD toolbox’ has its own particular limitations, just as a handsaw has its limitations within woodworking. Practitioners should remember that only when tools are used in the right situation, and in the proper way, they can be very effective despite their inherent limitations.

Tools, no matter how advanced, do not automatically confer their associated benefits. “People, processes and tools are jointly responsible for innovation and development. In fact, when incorrectly integrated into an organisation, new tools can actually inhibit performance, increase costs and cause innovation to founder” (Thomke, 2006, p. 24). Thomke’s conviction was that tools were only as effective as the people and the organisations using them.

In terms of tool shortcomings in Dutch companies, Nijssen and Lieshout (1995) found the main shortcoming was the time required for implementation and execution of the tools, followed by forecast inaccuracies, and the inability to capture the complexity of the marketplace. This corresponds remarkably well with the findings of Mahajan and Wind (1992) for companies in the USA. Nijssen and Frambach (1998) reported similar shortcomings encountered with NPD tools by the companies in their research, which included prediction inaccuracies (32%), long time for implementation (27%), high costs (23%), and time consuming processing (14%).

Research into specific tool limitations (Chai & Xin, 2006; Nijssen & Frambach, 2000), showed limited uptake of tools such as ‘QFD’, ‘DOE’, ‘FMEA’ and ‘conjoint analysis’ because of their perceived high complexity, high time consuming demands, and low user-friendliness. Others, such as the ‘BCG model’, had been abandoned by large firms due to their perceived limitations (an inability to adequately capture the complexity and turbulence of markets in the case of BCG (Schelker, 1976)).

In conclusion, it appears that much controversy exists surrounding the topics of tool satisfaction and usefulness. Some studies showed relatively high overall levels of tool satisfaction, while others showed just the opposite. The subjectivity problem in measuring satisfaction levels among users (which I discuss in detail in Section 4.5.11, p. 97), is further compounded by factors of which their impact may be unknown at the time of measurement, including the user's level of tool familiarity, and the appropriateness of using a particular tool in a certain circumstance. Past studies were all conducted among large firms, which beg the question whether practitioners in small firms have similar experiences with tools as their counterparts in large firms. Furthermore, past research succeeded to some degree in identifying factors that are associated with user's tool use experiences, but it has not always succeeded well in addressing the reasons behind those factors. Factors that were not at all considered in past research of tool usefulness include tool diffusion within projects and thoroughness of tool use. In addressing these factors, I define the corresponding null hypotheses as:

> *$H1^{useful}$: The level of tool adoption is not associated with managers' perceptions of tool usefulness*
>
> *$H2^{useful}$: The thoroughness levels of tool application are not associated with managers' perceptions of tool usefulness*

2.7 GAPS IN THE LITERATURE

In addition to the specific gaps in the literature that I identified in each of the sub-sections of Sections 2.2 to 2.6, I comment here on some general gaps in past research on NPD tools, and my attempt to address these in this thesis.

- Although I have found that NPD tools are prominent in practitioners' accounts of NPD activity, when reviewing the relevant research literature, I discovered that it painted a fragmented picture of NPD tool adoption, usage and impact on performance. I address these shortcomings in the current study by using the integrative frameworks developed in Section 2.2.6 and Chapter 3.
- In addition to finding the NPD tools literature fragmented, I also found that its focus on tools, practices and processes comes at the expense of attention to the day-to-day activity of NPD practitioners. It focused more on the set of tools practitioners use than on the praxis of how they used them. In this study, I address this problem in the first instance by developing NPD practice theory (Chapter 3) to guide my research and secondly by carrying out in-depth case studies into aspects of tool usage in specific projects.
- Very limited tool research has been done among firms employing less than 100 people. It is uncertain whether past research findings that stem from research among large firms, equally apply to smaller firms. For example, some international research has investigated the impact

of tool usage on NPD performance among large firms, but none has been done among smaller firms at either programme or project levels. The current study rectifies this situation by answering all of the research questions in the context of individual NPD projects that were executed in small high technology firms (refer to Sections 4.4.7 and 4.5.3 for information on firms studied).

- It seems that related research only succeeded in establishing correlations among independent and dependent variables, without any attempt to determine causality.

2.8 CONCLUSION

In this chapter, I presented a reflective review of the extant literature on NPD tools. To begin with, I described the methodology I used for carrying out this review. I next discussed the caveat that scholars face when studying NPD tools, and presented a tool definition and derived an integrative framework for studying NPD tools. This framework includes an articulation of twelve perspectives and a generic four-stage NPD process that are necessary to capture the full scope of NPD activity and tools. It also identifies and maps typical activities and tools in the existing literature onto each stage and perspective. The framework is crucial to this study as I used it to structure the format and content of the survey questionnaire.

An overview of the demographics of firms studied in the past pointed out the gap in the literature that exists for studying NPD tools in the small-firm setting. The sections on innovation and NPD in small firms contextualise NPD tools respectively in relation to its place in the bigger organisational setting, and against the backdrop of NPD activity in small high technology firms. Finally, I organised the extant literature pertaining to NPD tool selection and use into eight major themes with a clear logical link in this chapter. From this I was able to derive the research questions for this study, and where appropriate, corresponding hypotheses and investigative questions.

As such this chapter, and in particular the first four research questions, lays the foundations for constructing the survey questionnaire. However, in the absence of NPD practice theory, there is no guidance on how to conduct the case study research relating to the use aspects of tools (predominantly addressing research questions five to eight). In the next chapter, I develop such a theory that identifies all relevant constructs and relationships among them.

3 CONCEPTUAL DEVELOPMENT FOR STUDYING NPD TOOL USAGE

In this chapter, I draw on the strategy-as-practice literature to propose a conceptual model of the relationship between tools, practices, praxis and practitioners. This model demonstrates the contribution that tools and practices make to NPD activity and outcomes and lays the foundations for the case study part of my research (Chapters 6 and 7) that primarily addresses research questions five to eight. I furthermore suggest an integrative framework that seeks to unify the empirical contributions of this study and end this chapter by summarising the research implications of Chapters 2 and 3 for this study.

3.1 NPD CONSTRUCTS

In order to study NPD activity and tool usage in its broadest context, it is necessary to define a vocabulary and taxonomy that express the indirect relationship between practices and tools, at one level, and NPD activity within a project, at another. Drawing on practice theory, a key distinction between these levels is that practices (including tools) are always to some degree generic, whereas NPD activity within a project is always a one-off. The significance of this for studying NPD activity is that projects only *draw upon*, and cannot represent a *facsimile of*, generic practices, processes, or tools (Seidl, 2007). To further clarify this I have developed the model below by adapting Whittington's (2006) taxonomy of strategy practice.

3.1.1 Practices

Practices are multi-level shared routines of behaviour, including traditions, norms and procedures for thinking, acting, and 'using' things (Whittington, 2006). Firms can internalise practices through their operating procedures and culture. Practices also exist in industry sectors, or more generally in the literature and discourse of NPD in the environment outside the firm. A term often used in the NPD literature for describing practices is 'routines' - "learned patterns of behaviour which become embodied in structures and procedures over time"; "they are hard to copy and highly firm-specific" and seen as "the way we do things around here" (Tidd, et al., 2005, p. 80). Practices furthermore "…include the tools, technologies and know-how of the practitioner – the things the practitioner uses when engaged in [NPD]" (Balogun, Jarzabkowski, & Seidl, 2007). Thus, tools are a particular subset of NPD practices. In reality, however, some overlap among the various subsets of NPD practices makes it sometimes difficult to distinguish among the various subsets of NPD practices. I provide some examples for each subset in an effort to clarify the differences:

1) Tools (e.g. computer aided design, concept screening, in-market testing, stage-gates, TRIZ, brainstorming, concept screening (procedure), NPD process, tool adoption process, idea generation procedure);
2) Technologies (e.g. laser etching, stereo lithography, vertical molding, computer-integrated manufacturing - these are specific technologies in areas such as software, mechanical and electronic engineering and manufacturing);
3) Know-how (e.g. formal and tacit technological knowledge, knowledge about how to manage the NPD process);
4) Other routines (e.g. formats and frequencies of meetings, the ways in which success is celebrated and products are launched, approaches to job enrichment, resource allocation, sub-contracting, and professional development).

As discussed in Section 2.2 page 14, tools exist in many forms, including matrices, grids, tables, graphs, checklists, taxonomies, lists and software, together with combinations of these forms (Phaal, et al., 2006).

Over the years NPD practices have been thoroughly researched (Cooper, et al., 2004a; Cormican & O'Sullivan, 2004; Dooley, Subra, & Anderson, 2002; Kahn, Barczak, & Moss, 2006). Practitioners often use the term ‘best practice’ - those “methods, tools or techniques that are associated with improved performance” (PDMA, 2008a) or those “tactics or methods that have been shown through real-life implementation to be successful” (Dooley, et al., 2002, p. 3). In the conceptual model that I present here, improved performance comes from the individual execution of practices, not from the practices themselves. It is widely acknowledged that best practice is context specific and that companies need to adapt it to specific environments (Cormican & O'Sullivan, 2004; Kahn, et al., 2006). The term ‘effective practice’ therefore more accurately reflects the adaptation of practices that is inherent in praxis.

3.1.2 Praxis

The second core concept from Whittington’s taxonomy is praxis, a Greek word that refers to actual activity, what people do ‘in practice’. It refers to the execution of those steps and practices that an NPD team actually carries out as it undertakes a particular project. Because praxis refers to the actual interpretation and execution of steps and practices, it is always a one-off, non-repeatable, live performance. Praxis includes the more mundane aspects associated with NPD, such as project meetings and team briefings (Balogun, et al., 2007).

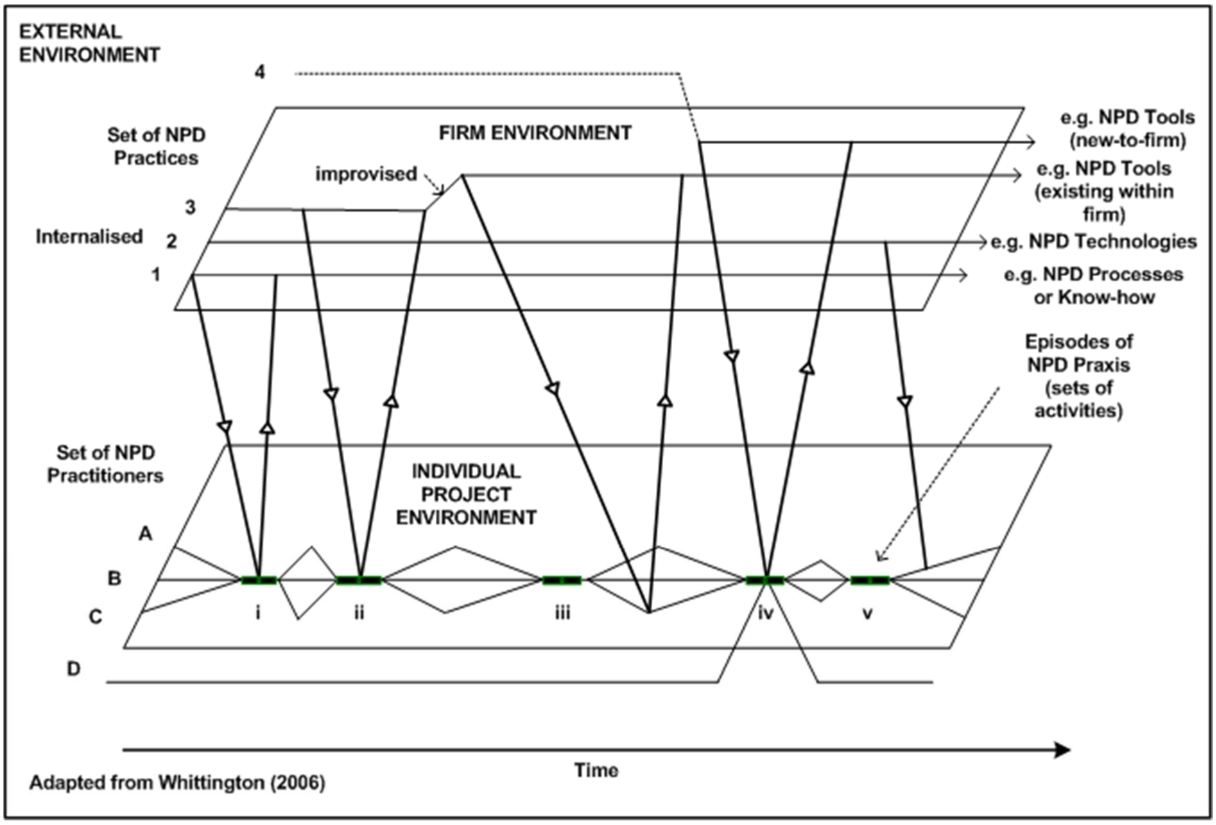
3.1.3 Practitioners

The third concept in Whittington's adapted taxonomy is NPD practitioners, the innovation actors who select and perform NPD activities and carry out its practices. NPD practitioners are normally members of cross-functional teams and are found over many levels in the organisation, and even outside the organisation (Di Benedetto, 1999; McDonough, 2000). When carrying out activities, practitioners draw from the pool of practices and apply them to specific, concrete situations (Seidl, 2007). In doing so, they inevitably adapt the practices they draw on, both because of the context-specific interpretation of the abstract practice (Orlikowski, 2000) – 'practice-in-use' – and because they may intentionally use practices in ways different from their original intended purpose (Jarzabkowski, 2004). Hence, 'practice-in-use' is often associated with artful performance, synthesis, improvisation, and adaptation.

Figure 8, adapted from Whittington (2006), joins the three core concepts of praxis, practices and practitioners within an integrative framework of NPD practice at the project level. It furthermore depicts the execution of praxis in a typical NPD project. The bottom parallelogram represents five points of convergence in episodes of intra-organisational NPD praxis (i to v) and the involvement of three practitioners of the same organisation (for convenience A-C), and one outside practitioner (D) in episode iv. Practitioner D is part of the external environment, perhaps a sub-contractor or consultant, indicated by the outside, all-encompassing box. These praxis episodes might be formal stage-gate meetings; they might be project or informal meetings. As the practitioners engage in NPD activities, they draw upon the set of accepted and legitimate organisational practices (for convenience again, just 1-3), shown in the upper parallelogram. Such practices will likely comprise both locally generated routines and practices originating from within the external environment.

On occasion, as shown by the kink of practice 3, practitioners may find it desirable to modify the company's routines in the light of experience. On other occasions, such as at episode iv, practitioners may find it necessary to, in order to cope successfully with new challenges in a current project, draw upon useful practices such as practice 4 that have not previously been adopted by their organisation. In doing so, they may add them to the stock of routines from which practitioners will draw during subsequent NPD projects. At the firm level, the driving forces behind the adoption of tools into the organisation are institutional forces motivated by efficiency and legitimacy gains (Westphal, et al., 1997).

Figure 8. Integrating NPD praxis, practices and practitioners



In a particular project, however, individuals select and apply tools based on their knowledge of existing and emerging tools, and the particular demands of the project. When they apply new tools, they may add them to the stock of practices/routines from which practitioners will draw during subsequent NPD projects. During this process, the practices may also be amended to better suit particular organisational contingencies.

3.2 IMPLICATIONS FOR THIS RESEARCH

Having set out a comprehensive integrating model of NPD activity in the context of practice, practitioners and praxis, in this section I develop an integrative NPD tool research framework that facilitates NPD tools, activity, practitioners and performance. Figure 9 conceptually integrates the set of eight research challenges in Table 6 (page 43) with the concepts developed in Chapters 2 and 3. It shows how NPD team members draw from existing and emerging 'best practice', from practitioners outside the organisation, and from the pool of internalised practices within the organisation, when executing individual NPD projects. The resulting project praxis are unique for each project. Individuals play different roles and team composition varies; each project uses a different form of process with a different balance of perspectives and associated activities; the team makes different choices of tools and applies them differently; and the team executes each project in a unique fashion.

In Figure 9, research topics 1-3 (corresponding Sections 2.6.1 to 2.6.3 of the literature review) look at the influences on firms adopting tools as part of their standard processes or routines (the practice aspect of tool use). Topics 4 and 5 (corresponding Sections 2.6.4 and 2.6.5) look at NPD practitioners' familiarity with tools and factors that influence them in selecting tools in their projects. Finally, topics 6-8 (corresponding Sections 2.6.6 to 2.6.8) consider how individuals use and evaluate tools, and the effect tools have on projects (with the focus on tool praxis).

Figure 9. An integrative framework for studying NPD activity and tools

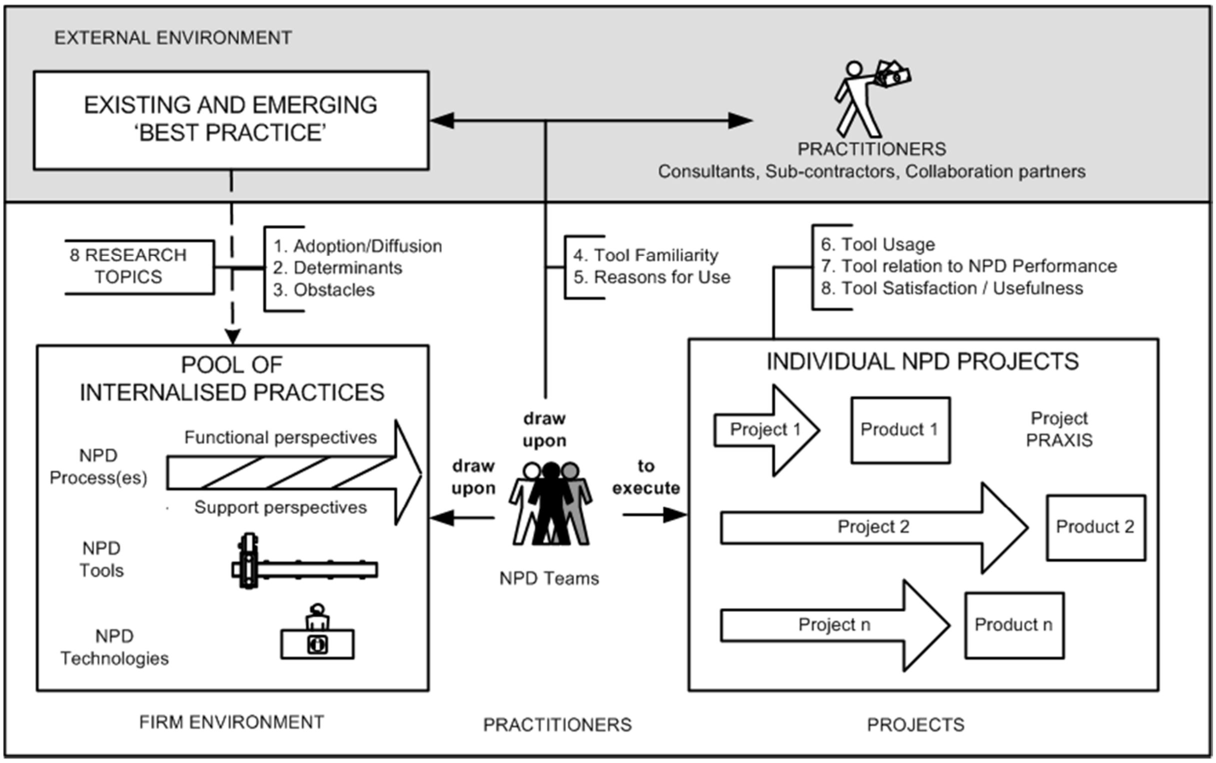


Figure 9 and Table 6, in conjunction with the multi-perspective NPD framework summarised in Figure 5 (p. 26), facilitate more comprehensive research into NPD activity and tools than was possible before. By outlining a full set of perspectives and research topics, they demonstrate the scope that this research will cover. Only by piecing together findings from all of the perspectives and research topics will it be possible to gain as complete as possible a picture of tool application among small high technology firms. By using this approach, I address the risk that emphasising a limited number of NPD perspectives may compromise the others, and hence may inadvertently compromise the performance of the NPD process or new product, or both.

3.3 CONCLUSION

Research on NPD activity and tools is made complex by the number of types of NPD activities in even the simplest innovation project, and by the correspondingly large number of tools available to practitioners. The development of NPD practice theory in this chapter complements the multi-stage, multi-perspective framework that I developed in Chapter 2 (Figure 5, p. 26) by integrating process and tools in a way that aligns with the needs of NPD practitioners.

This chapter furthermore builds on the constructs and models developed in Chapter 2 in designing and presenting an integrative NPD framework as a basis for rigorous study of NPD activities and tools. This integrative framework goes further than previous attempts, which by the nature of their design excluded important NPD perspectives and tool categories. By using this framework, my research can deliver a better and more comprehensive understanding of NPD tool application and use as it is able to integrate the findings of my mixed-method research approach.

4 METHODOLOGY

4.1 INTRODUCTION

In Chapter 2, I developed a conceptual framework of a generic NPD process suitable for facilitating NPD tool research in ways to overcome the identified shortcomings of previous research (see Section 2.7, p. 63). Through a detailed review of NPD tools and activities, I showed how twelve perspectives and four stages can coherently categorise these tools and activities. By using this framework in conjunction with the NPD activity theory developed in Chapter 3, the current research sets out to deliver a comprehensive understanding of NPD tool application and use among small high technology firms, across all of the eight main areas of tool research shown in Figure 9, p. 69.

This chapter provides a comprehensive review of and justification for the mixed-method survey and case study research methodologies and choice of research variables and measures used in this research.

4.2 RESEARCH UNIT

The unit of research for both the questionnaire and case study research methods is an individual NPD project that high technology New Zealand firms completed within the past four years.

4.3 RESEARCH STRATEGIES

As the research questions in Section 1.4 (p. 4) represent exploratory, descriptive and explanatory-type research, this study applies a deductive research design in adopting a combination of survey method (the tailored design method) and case study method, in this order. The tool questionnaire contains mostly quantitative type questions and was administered via an online survey (see Appendix 3), by invitation to a sample of 566 firms (Section 4.4.5 describes the sampling process). Its purpose was to obtain an all-embracing overview of tool use among small high technology firms, paving the way for the follow-up, in-depth explanatory case study research conducted among five firms. Case study method is the preferred method when ‘how’ and ‘why’ questions are asked, when the researcher has little control over the events and the focus is on a contemporary phenomenon within some real-life context (Yin, 2003). A detailed discussion of the survey and case study methodologies used in this research follows in the next two sections of this chapter.

4.4 SURVEY QUESTIONNAIRE

4.4.1 Justification for Using an Online Survey

An online survey was chosen over a conventional mail survey for several reasons, of which the convenience factor was probably the biggest. Online surveys have several advantages over mail surveys ("Tools for Organizational Development," 2008):

- **Comparable or lower costs than paper**. After careful comparison and consideration of a wide variety of Web survey software, I decided to use LimeSurvey version 1.71+, an open-source script written in PHP. This script can be downloaded free of charge at www.limesurvey.org. I uploaded and installed this highly customisable script on a Web server which I rented from WebFarm (www.webfarm.co.nz) at a monthly cost of NZ$20, and registered the domain www.toolsurvey.com for this purpose.
- **Short project turnaround time; 2-4 weeks**. My survey ran for only 18 days during which time I obtained a 22% response rate and a sample that represents the survey population.
- **Preserves anonymity and encourages candid feedback**. The survey was 'by invitation only' to a predetermined selected audience whom I sent unique tokens (four-digit access codes) that provided entry to the questionnaire. It was therefore possible to maintain strict access control, thus ensuring that only legitimate participants completed the survey, while at the same time maintaining anonymity. Several respondents provided positive feedback after completing the survey, expressing their interest in the findings.
- **Ease of use/Convenience**. Participants were given the Web address and with their provided tokens, they got easy access to the seven-webpage survey that they were able to complete within 20 minutes by systematically clicking through the questions leading up to the last 'Thank you' page. There was therefore no need to mail the completed survey back to me.
- **Immediate access to data and reports**. LimeSurvey has several advanced features, including the ability to notify the survey operator of new responses and providing access to individual and aggregated responses received up to a particular point in time. It was possible to import the final dataset directly into SPSS (a computer program used for statistical analysis) for more advanced analysis.
- **Customisable and programmable logic**. I branded the survey with the University of

Canterbury logo and made it visually appealing through the effective use of colours and easy-to-read font size. I designed skip patterns into the survey, which made it possible for respondents to answer certain questions for only those tools that they previously selected, thus effectively shortening the survey. The ability of screens to adapt to initial responses (such as lists of tools) and hence provide a much simpler and less off-putting interface for users is a huge advantage over paper surveys. Pop-up information screens provided brief descriptions of each tool if respondents felt the need to access them.

- **Eliminating missing data**. LimeSurvey uses JavaScript that prevents respondents from proceeding to the next question without having fully completed the current question. The implication is that my completed dataset had no missing data.

4.4.2 Questionnaire Construction and Measures

I developed an online questionnaire (Appendix 3) from the relevant literature on product development, marketing and technology management, deriving most of the questions and measures from past research. The quantitative-type research questions in Section 1.4 (p. 4), combined with the 12-perspective NPD process framework (see Figure 5, p. 26), guided the compilation and format of the questionnaire, which consisted of seven major sections (Sections I to VII). Unlike some studies that investigated tool application at the programme or company level, my study uses a specific project as the unit of study. Consequently, in some cases my choice of measures would therefore be slightly adapted and differ from similar past research to accommodate my focus on projects. In what follows, I provide an overview of each of the seven sections in terms of what was measured and how I derived the questions and measurement scales.

Section I covers some general background information about the specific project under consideration that resulted in the launch of a specific product. For the straightforward questions such as the number of people involved in the project and their experience, and project duration, I used ordinary interval and/or open-ended scales. In categorising the type of project used and determining the experience of the core development team for the particular project, I used the established category definitions of Booz, Allen and Hamilton (1982) that have been widely used by the likes of Adams (2004) and members of the Product Development and Management Association (PDMA) (see Section 2.3.2, p. 32).

Section II covers some general background information related to the NPD process and innovation strategy that guided the implementation of the project under consideration, and includes four questions. As a detailed study of innovation strategy falls outside the scope of this thesis, I used a simple dichotomous scale to establish whether the project was guided by a strategy (yes), or not (no), in line with previous research (Adams, 2004). To improve external validity, I provided the one-sentence explanation: *'Innovation strategy: The firm's written positioning statement for developing new technologies and products'.* Next, to determine the NPD process that most closely described the one followed for the project, I again reverted to Adams (2004) who used a four-scale categorisation (Section 2.5.1, p. 39). Testing for the number of major development stages in the process was achieved with an open-ended question that only accepted numerical values, instead of providing a set of eight categories as Nijssen and Frambach (2000) did where each category represented a stage, except for the 8th category which represented 8 or more stages. In my questionnaire participants were instructed to enter a '0' if no standard approach to NPD was followed (which necessarily implies zero stages). The origin of the fourth question in this section – addressing the level of consideration given to various NPD aspects - stems directly from the 12-perspective framework that I developed in Section 2.2.6 (Figure 5, p. 26). As such, measurement of these constructs has not been undertaken in past research, leading me to develop an attitudinal measurement scale for measuring participants' perceptions of the degree of consideration they have given to each of the 12 perspectives during the development of the product. I used a 5-point Likert-type scale for this purpose where 1 = very little consideration and 5 = very much consideration. I also provided a 'not applicable' option.

In section III, respondents were asked to indicate from a categorised list of 76 tools which ones they used in their development projects (the tool categories were derived from the 12-perspective framework). The choice of tools followed from a narrowed-down selection of the tools in Table 4 (p. 29), based on tools used in similar research and those believed to be most commonly used in practice and associated with modern NPD. The final list of 76 tools obviously does not contain (and was not intended to contain) all of the existing NPD tools. There are three widely accepted methods for measuring the dependent variable 'tool adoption'. The first method is measuring frequency of use (Calantone, Di Benedetto, & Schmidt, 1999; Nijssen & Frambach, 2000) - e.g. using a 3-point Likert-type scale where 1 = infrequently and 3 = frequently. The second method measures the importance ratings of tools (Maylor, 2001), e.g. using an 11-point Likert-type scale where 0 = not important and 10 = important (Maylor, 2001). The first two methods are only suited to measuring tool adoption at the programme or business/business-unit level where respondents are questioned as to their use and experience of tools in general. As such, these measures were not suitable to this research where the unit of study is a single project. Hence, I reverted to using a third measure where the emphasis is on the level of application (Chai & Xin, 2006; Cristiano, Liker, & White III, 2000), using a 5-point Likert-type scale where 1 = not thorough and 5 = very thorough. (Chai & Xin (2006) actually used this measure slightly differently by referring to thoroughness in the leading question and asking respondents to rate it based on a scale where 1 = very low and 5 = very high. I do not believe the difference in semantics is significant, though.) To cater for situations where a tool was not used in a project, I included the option 'Not applicable (not used)' in my questionnaire. Having measured tool adoption in this manner, I subsequently created two more adoption-related variables to cater for (1) tool diffusion among firms and (2) tool diffusion within projects (refer to Section 2.6.1(p. 44) for definitions of these terms). The former variable is simply the sum of all occurrences where thoroughness levels were indicated as either 1, 2, 3, 4 or 5 for an individual tool, among the 99 firms in the sample. The latter variable is simply a frequency count of the number of tools implicated as having been used across a single case (project).

Section IV in the questionnaire deals with tool satisfaction. As I explain in Section 5.2.8, (p. 119), the focus in this study is one aspect of satisfaction, namely the perceived usefulness of a set of tools. The question and scale format take the same form as in Section III (tool adoption), except for the measures used where 1 = not useful and 5 = very useful. This measure is exactly the one used by Tidd and Bodley (2002) and Farris et al. (2003).

There are two sub-sections to Section V: (1) a question that deals with a list of tool obstacles that were identified from the literature review where respondents were simply required to check any that applied, and (2) a list of potential tool determinants that also originated from the literature review. In this case all the independent variables (determinants) were operationalised, in line with the work of Tidd and Bodley (2002), as a multi-item list using a 5-point Likert-type scale. In the resulting matrix each tool determinant was put forward as a positive statement and participants could rate their level of agreement with each statement (1 = strongly disagree and 5 = strongly agree).

Section VI of the questionnaire deals with NPD performance measurement, where the choice of dependent variables (performance measures) was not an obvious one. The NPD literature suggests numerous NPD performance measures (Griffin, 1997a; Griffin & Page, 1996; Hertenstein & Platt, 2000; Kleinschmidt, 1994; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995; Pun & Chin, 2005; Ulrich & Eppinger, 2008; Yeh, et al., 2008b), far too many to consider in a single study. Hertenstein and Platt (2000) suggested that NPD managers prefer non-financial to financial performance measures for two reasons. Firstly, non-financial measures more directly assess critical strategic dimensions such as customer satisfaction, time to market, and product quality, than financial measures are able to. Secondly, because of the lag between NPD work and product launch and due to the difficulty in separating NPD financial results from those of other functions such as marketing or manufacturing, non-financial measures are preferred. I therefore select and include 12 of the most frequently used non-financial measures, with the exception of product profit margin, in the current research, ensuring a satisfactory coverage of measures in both product and process. Five of these measures are process-related, and seven product-related. Measures in the former category are: Speed to market, launched on time, adherence to budget, degree of inter-functional cooperation, degree of external cooperation. The seven product performance measures are: Customer acceptance, customer satisfaction, product profit margin, meeting performance specifications, meeting quality specifications, delivering competitive advantage to the firm, and finally, serviceability. I purposely did not include any post-launch performance measures as such measures have the potential to be affected by factors outside the NPD process – outside the domain of tools included in this study. In this study, the measures ‘customer acceptance’ and ‘customer satisfaction’ are included to measure managers’ perceptions of these factors based on the limited pre-launch information available to them through using tool such as ‘voice of the customer’, ‘in-market testing’, ‘limited roll-out’, etc. As such, these variables do not reflect actual market performance or actual customer responses after these products were launched.

As such performance was measured by means of a multi-item measure consisting of 12 items, using the 5-point Likert-type scale of Yeh, et al. (2008b). In addition, I added two more options (1) ‘I don’t know’ and (2) ‘Not applicable’ to respectively allow for instances where respondents did not know how to rate a particular performance area due to a lack or unavailability of information, and to allow for situations where a particular performance measure was not important, or irrelevant.

The final section of the questionnaire focuses on the demographics of the participating firms. Two questions deserve specific mentioning: (1) Company size was operationalised based on (a) the firm’s number of full-time employees (six categories), of which the scale was chosen with New Zealand’s definition of Small and Medium-size Enterprises in mind (firms employing 19 or less full-time equivalent staff). (2) Company size was also operationalised on (b) annual company turnover (seven categories), with the second biggest category specifying annual sales in the bracket NZ$51 to 100 million – which is indicative of the small size of companies included in this study.

Scale merits and limitations

It is obvious from the above discussion that many of the chosen measures make use of Likert-type scales, which are by nature qualitative. In recent decades it has gained wide acceptance in many areas of research that include psychology, marketing, organizational behavior, and of course NPD. Measures obtained from Likert-type scales are perceptual, as they are based on participants' subjective ratings of the study's variables, for example, when using a 5-point ordinal scale to measure a continuous variable such as performance, where '1' indicates 'poor' and '5' indicates 'excellent' (if it were possible to measure performance directly, the measurement scale would be continuous). Used in an ordinal manner, Likert scaling thus presumes the existence of a continuous variable (performance) whose value characterises the respondent's opinions or attitudes. This approximation is widely accepted for situations where the number of observations are sufficiently large (as is the case in my study: N = 99), where adding the responses and calculating the mean is legitimately regarded as a continuous interval variable on which parametric tests can be used (Page & Meyer, 2000). Despite the extensive use of perceptual data in NPD research, shortcomings associated with subjective measures that include potential inconsistency among members of the same project team and the use of a limited number of discrete or ordinal scales used, should not be ruled out.

For practical reasons that include time constraints, I was only able to employ the single-source, self-rated methodology (one key informant per project) in the current study, which is consistent with other NPD studies (Araujo, et al., 1996; Chai & Xin, 2006; Thia, et al., 2005; Yeh, et al., 2008b). While this approach may cause artificially high inter-correlations because of an overall positive or negative response bias, simply assuming that single-source data are less valid than multi-source data is overly simplistic (Avolio, Yammarino, & Bass, 1991). Despite potential drawbacks, perceptual (subjective) measures could prove quite meaningful as the origin of the perceptions – managers – is also the audience.

All the measures in the survey are post-hoc which is unavoidable and typical for this kind of research. Steps taken to compensate for post-hoc effects include questioning participants on one very specific project that was completed in the not-too-distant.

4.4.3 Pre-testing the Survey

Prior to administering the survey, I followed the four sequential stages of the pre-testing process (Dillman, 2000):

Stage 1: Review by knowledgeable colleagues and analysts. Three academics, two from the University of Canterbury, and the other from Massey University, were involved in this activity. Steps that ensured content validity of the questionnaire included verification and contribution by experts, and as stated before, the provision of clickable pop-up operational definitions (Page & Meyer, 2000) of all 76 NPD tools, conveniently placed on the web pages.

Stage 2: Interviews to evaluate cognitive and motivational qualities. I combined this stage with the previous one, ensuring clarity and understanding of words, and similar interpretation of questions. I used the five most popular Web browsers (IE, Firefox, Opera, Apple Safari, and Google Chrome) to check for correct functionality and consistency in appearance.

Stage 3: Small pilot study. This stage involved two academics and four NPD practitioners. The method I followed to test and improve the survey, was to get feedback from the first person, evaluate and implement the proposed changes, and get the next person to test it, until I was certain the survey could not be improved upon.

Stage 4: A final check. Prior to launching the survey, I completed a dummy run of ten responses to verify the correct functioning of the database and exportability into SPSS. This stage involved several people who had nothing to do with the development or revision of the survey.

4.4.4 Survey Reliability and Validity

The online survey predominately uses perceptual (subjective) measures as the use of third-party measures was not practical. While Ketokivi and Schroeder (2004) proposed that both the reliability and validity of perceptual measures are satisfactory, relying on a single informant or ignoring informant bias can lead to biased estimation of substantive parameters. I sought to minimise potential bias by requesting ratings for a specific, recent project and by using 5-point Likert-type scales for the dependent variables and nominal and ordinal scales for the independent variables. In addition, I used 12 separate measures of performance and my analysis considers these measures differentially. Following Graetz, et al. (2006) I addressed external validity of my findings by drawing on concepts that are commonly used in the extant literature, defining them with as little ambiguity as possible, and ensuring a sufficiently large data set. This validity is of course limited to the unit of analysis of this study and subject to the limitations discussed in Section 4.6.1 (p. 98).

To estimate the internal reliability of the only multi-item performance measure in the questionnaire, I calculated Cronbach's alpha coefficient as 0.878. While there is not a generally agreed cut-off value for this coefficient, values above 0.7 are widely accepted for this type of research (Bowman & Ambrosini, 1997; Nunnally, 1978).

With respect to construct validity, my questionnaire utilises established scales and questions that have very good levels of reliability and validity in the NPD literature (Chai & Xin, 2006; Nijssen & Lieshout, 1995; Yeh, et al., 2008b). The pre-testing steps of Section 4.4.3 (p. 78) explain how I ensured the instrument's content validity.

I conclude from these results that the construct validity of the questionnaire and the reliability of the questions are trustworthy.

4.4.5 The Survey Population and Sample

The study focused on New Zealand high technology firms that are engaged in NPD activity, with the emphasis on engineered, discrete, physical products and software (excluding process-intensive products and primary industries). The New Zealand manufacturing sector consists of approximately 6,000 firms (2007 data) in the C28 Category: Machinery and Equipment Manufacturing ("Business demography tables," 2007), but it is impossible to tell how many of these are involved in NPD. One challenge in selecting firms for the survey was the lack of a list of companies that are known to carry out NPD in New Zealand. As New Zealand is a small country, I compiled a fully inclusive database of 566 'qualifying' firms from private lists of companies, a Web site of New Zealand exporting firms (http://www.marketNewZealand.com), and directories of New Zealand firms known to be active in NPD (e.g. http://www.finda.co.nz). I mailed invitations (see Appendix 2) on university letterhead, with unique survey access passwords, to the Chief Executive Officers of all 566 NPD firms in the database, requesting them to have the survey completed by the most appropriate person in the organisation. I followed this up with two email reminders within a couple of days of each other to those firms that had not yet responded, to complete the online survey. As incentives to complete the survey, each invitee received a NZ$1 lottery ticket, the option to be entered into a draw for 20 NZ$50 petrol vouchers, and a promise of sending respondents a summary of the research findings, should they so prefer. Dillman (2000) stated that evidence is particularly clear that token financial incentives of a few dollars included with the request are significantly more effective than much larger payments sent to respondents after completion.

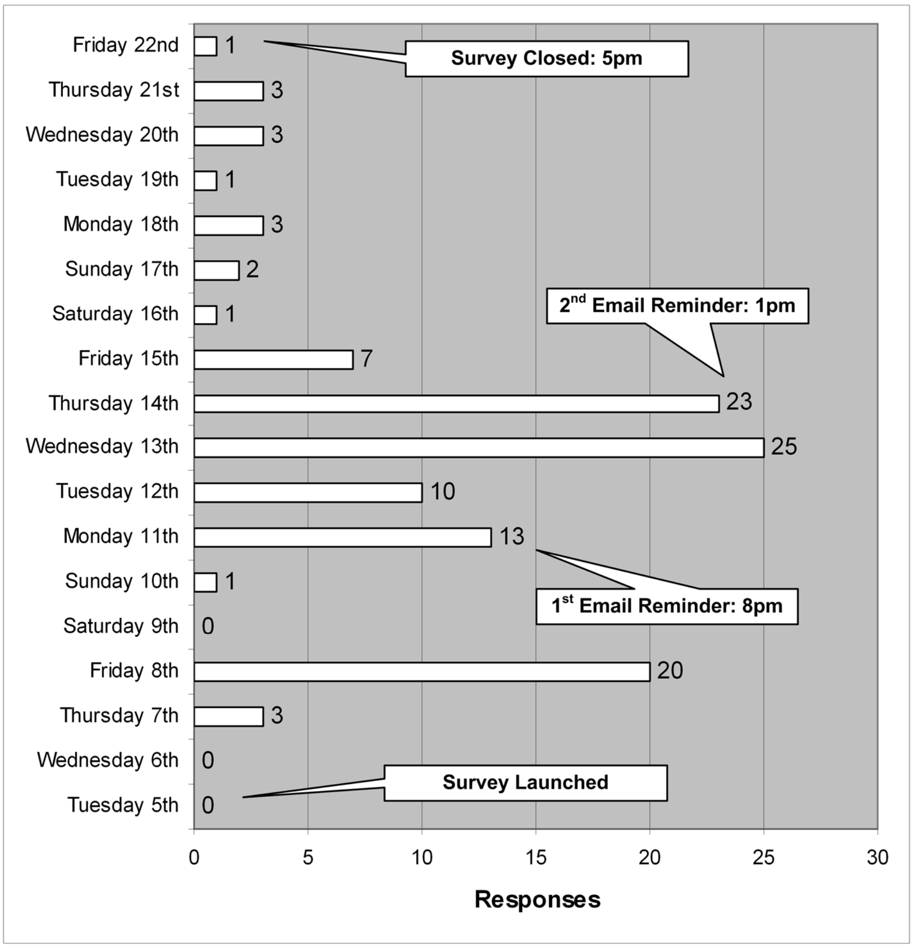
4.4.6 Administering the Survey

To achieve the best possible response rate, I used a system of four contacts:

1. A one-page letter of invitation, sent by mail on Tuesday the 5th of August 2008. As an incentive to complete the survey, I attached a one dollar (New Zealand) Instant Kiwi lottery ticket to each invitation.
2. A first automated email reminder to those firms that had not yet responded, sent at 8:00pm on Monday 11 August 2008.
3. A second and final automated email reminder to outstanding respondees on Thursday 14 August, at 1pm.
4. An automated thank-you email to all respondents.

Figure 10 shows the response rates I obtained over the 18-day life of the survey.

Figure 10: Survey response rates (August, 2008)



4.4.7 The Completed Sample

My contact strategy resulted in a response rate of 21.4% (112 completely filled-out responses), after accounting for 43 cases of undelivered mail. This is an acceptable response rate given a relatively lengthy questionnaire. Three cases were not suitable for quantitative analysis and ten were identified as outliers, resulting in a completed sample of 99 firms, which is representative of the population for a margin of error of ±10%. As such, the cleaned data set is free of missing values, representing complete sets of responses on a variety of measures for each tool. A possible limitation in constructing a sample in this manner is that the majority of firms that responded are, by self-selection, relatively innovative. The issue of self-selection is inherent in constructing a sample in this manner as participation is always voluntary. With this in mind, the findings of this research reflect the upper quartile for the level of engagement with NPD tools by high-technology firms.

Figure 11 provides a breakdown of the sample's 99 projects in terms of project strategy. Among the 99 projects, 35% are incremental innovation projects (cost reductions, repositioning of current products, and incremental improvement to current products); 37% are more innovative projects (addition to existing lines and new-to-the-firm products); and 28% are radical innovation projects (new-to-the-world products), providing a fairly even spread of projects among these three categories. The final sample represents 40% consumer and 60% industrial NPD projects. The breakdown of type of business is 46% manufacturing firms and 27% technology start-ups, with the remainder as "other" (government research agencies, engineering firms, consulting firms, etc.). Based on those who gave an industry (SIC category) for the firm, the breakdown is software technology (30.9%), hardware and equipment (22.0%), industrial (16.1%), energy and power (10.3%), household and personal products (5.9%), consumer durables (5.9%), food, beverage & tobacco (4.4%), aerospace & defence (1.5%), pharmaceutical & biotechnology (1.5%), and automobiles & components (1.5%).

Figure 12 indicates that approximately two thirds of the firms in the completed sample can be considered small-to-medium size (SME) enterprises (as defined in the New Zealand context), employing between 1 and 19 full-time equivalent staff. Furthermore, 45% of firms in the sample actually employ less than 10 full-time equivalent staff, a category of firms defined as Very Small Enterprises (VSEs) (Christofol, et al., 2009).

When comparing my sample distribution (in terms of the number of full-time equivalent staff employed) with New Zealand's national figures for (1) general business and (2) the manufacturing industry, I find that my completed sample is proportionally slightly under-represented in the 1-19 full-time employee category, and slightly over-represented in the 20-99 and 100+ categories.

Figure 11. Sample characteristics

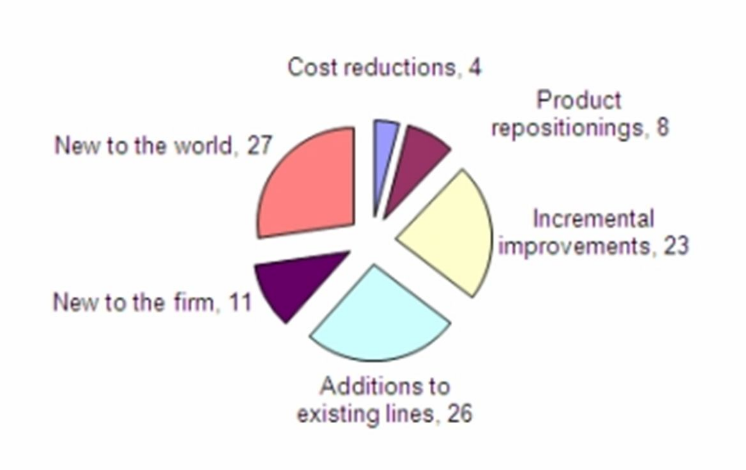
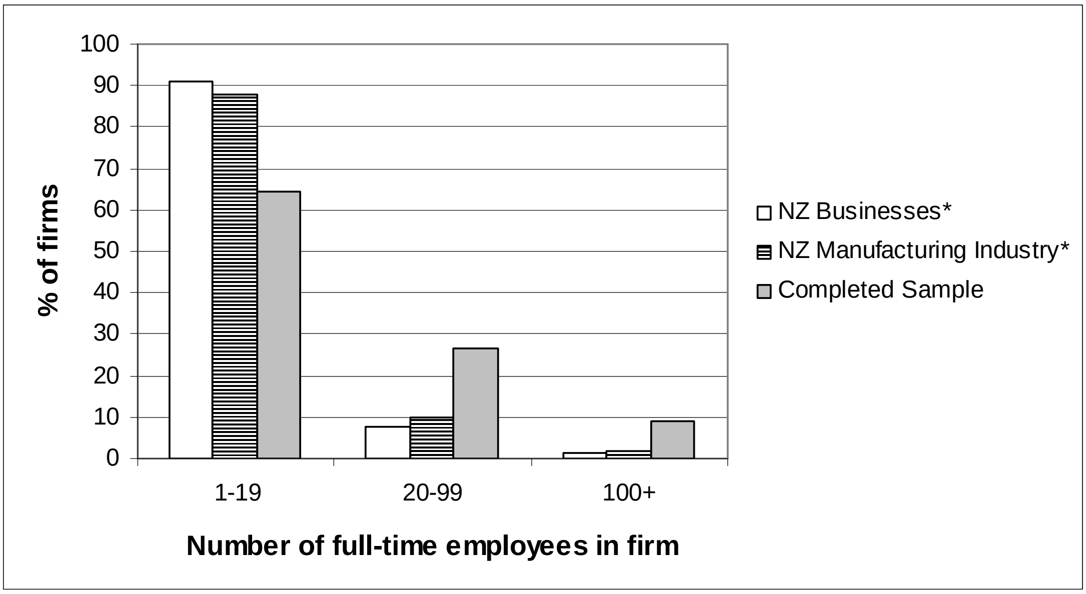


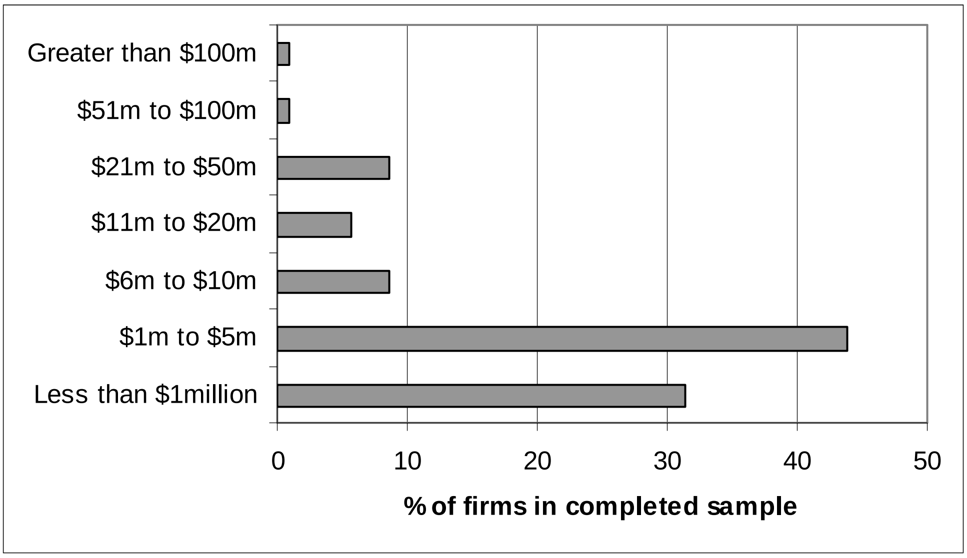
Figure 12: Firm size (number of employees)



* Source: Statistics New Zealand (www.stats.govt.nz) 2007 Tables

Figure 13 shows that roughly one third of the completed sample consists of firms having less than $1 million annual turnover, while exactly 75% fall below the $5million annual threshold, the majority of firms (44%) falling in the $1 to $5million band. In world terms, the participating firms in this study are significantly smaller than those in similar overseas studies with regard to annual turnover.

Figure 13: Annual turnover of firms in completed sample

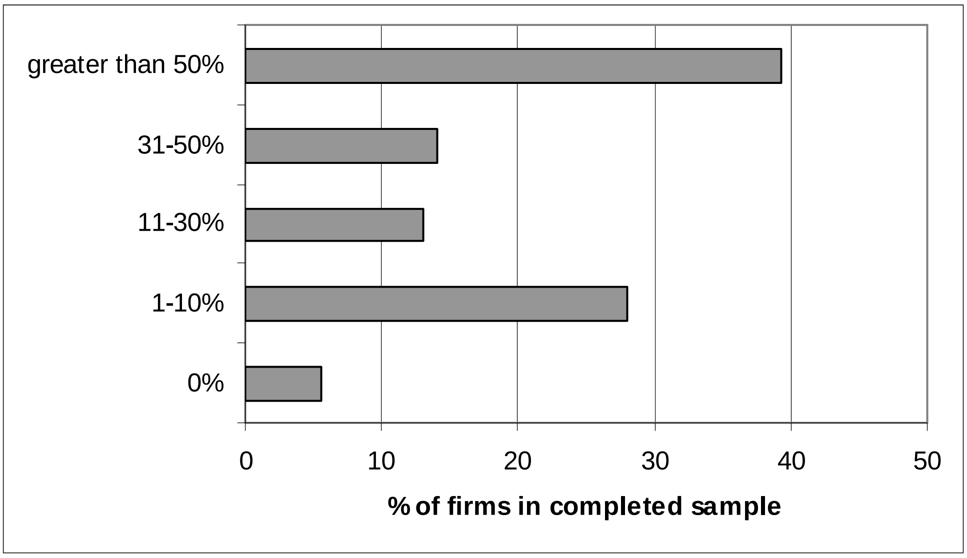


Yet another indicator of relatively small firm size in this research is the number of people involved in the projects under consideration. Three quarters of the represented NPD teams consist of five or fewer people; 18% have between six and ten people, with the remainder having 11 to 20 members. Not even one project involves more than 20 people. Surprisingly, I found that none of the past research gave any indication of the size of the NPD project teams. Common sense would lead one to believe that the number of people involved in NPD project teams, at least within the organisation, is proportional to firm size, hence the assumption that the average team size in this study is significantly smaller than that of past research.

Considering that seven firms in the completed sample categorised themselves as 'technology start-ups in incubators' that presumably have not achieved sales, it appears from Figure 14 that most firms in the completed sample are to some degree active in the export markets.

Ideally, I wanted NPD project managers to complete the survey, but found instead that 59% of the surveys were completed by the firm's CEO or one of its directors. Since New Zealand firms are so small, these people are very hands-on as is evident from the overall respondents' indicated overlapping areas of responsibilities for the projects under consideration: Technical/R&D: 74%; Marketing: 46%; Market research: 39%; Finance: 44%; Manufacturing: 30%; Quality assurance: 41%. The rest were completed by project managers, process managers, or somebody familiar with a particular project.

Figure 14: Sample firms' export earnings as % of total sales



4.4.8 Sources of Survey Error

There are four sources of error to consider when using surveys of this type (Dillman, 2000):

1. The sampling error is the result of surveying only some, and not all, elements of the survey population. As explained above, it was impossible to determine the exact size of the survey population (Np). A reasonable estimate is Np=4,000, which yields a 9.1% sampling error (confidence interval) at the 95% confidence level. This implies, for example, if the survey found that 50% of the respondents indicated they did use a particular tool 'very often', that if the survey were conducted 100 times, the percentage who say they use this tool 'very often' will range between 40.9% and 59.1% most (95%) of the time. In reality though, the true population could be much smaller, probably in the region of 1,000, which would result in a sampling error of 8.73%.

2. The coverage error is the result of not allowing all members of the survey population to have an equal or known nonzero chance of being sampled for participation in the sample. I did not follow a sampling method as my aim was to construct a sample frame that effectively approached the total population. In the end, I am confident that I invited not only the majority, but also the most prominent and significant players in the New Zealand industry, as I compiled the sample frame from the best sources and contacts available to me.

3. The measurement error is the result of poor question wording or questions being presented in such a way that inaccurate or un-interpretable answers are obtained. The pre-testing (described above) would ensure that this error is minimised.

4. The non-response error occurs when the participants differ in some systematic way from the responses of non-participants. Included in the 78% of people who did not respond (a 22% response rate) are 47 respondents (8.98%) who partially completed, but then aborted the survey, presumably because they found it too long or they might have been interrupted by other work activities and did not return to complete it.) Miller and Smith (1983) stated that non-response error could be a serious threat to the external validity of a study, even for studies with response rates as high as 90%. Lindner, Murphy, and Briers (2001) proposed three protocols and procedures for addressing non-response error. They are (1) the comparison of early to late respondents, (2) using ‘days to respond’ as a regression variable, and (3) a comparison of respondents to non-respondents. Having considered the practicality of these procedures, the first two transpired as the most appropriate ones to use for the current study. It was not possible to use the third protocol as the survey was anonymous, which meant that I could not determine from my database which firms have not responded. (An in-built privacy function of the LimeSurvey software allows it to distinguish between respondents and non-respondents for the purpose of sending out reminders to non-respondents, but it does not make that information available to the survey administrator.)

Method 1: comparison of early to late respondents

This method was developed by Armstrong and Overton (1977) who proposed ‘extrapolation methods’ for estimating the response of non-respondents. It is based on the premise that subjects who respond late are similar to non-respondents. Until the present time some controversy exists around defining the term ‘late respondent’. The authors operationalised late respondents as those responses generated by “successive waves of a questionnaire. ‘Wave’ refers to the response generated by a stimulus, e.g., a follow-up postcard” (Armstrong & Overton, 1977, p. 397). In the case of my study, I define late respondents as those who responded in the last (3rd) wave of responses after Thursday August 14, 2008, that is, in response to the second email reminder that I sent out at 1pm (see Figure 10, p. 80). (The first email reminder sent out on Monday 11 August triggered the second wave of responses.) The third wave consisted of 21 responses received during the period 15 to 22 August, plus 13 responses received on 14 August between 1pm and midnight, thus giving a total of 34 ‘late respondents’. This number is within the protocol’s suggested threshold of 30 responses to ensure that the number of late respondents is large enough to be meaningful practically and statistically. To conclude this procedure I compared the means in ‘diffusion within projects’ (the primary variable of interest) between early and late respondents in Table

10. As no statistically significant differences could be found between early and late respondents in Table 11, I conclude that, according to this methodology, the non-response error is negligible and that my results can be generalised to the target population.

Table 10: Comparison of descriptive statistics for early and late respondents*

Res-ponses	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Early	65	23.75	12.945	1.606	20.55	26.96
Late	34	23.76	12.287	2.107	19.48	28.05
Total	99	23.76	12.660	1.272	21.23	26.28

* Test variable: tool diffusion within projects

Table 11: ANOVA results (diffusion within projects) for early and late respondents

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.003	1	.003	.000	.997
Within Groups	15706.179	97	161.919		
Total	15706.182	98			

Method 2: using 'days to respond' as a regression variable

In this procedure, 'days to respond' is coded as a continuous variable and used as an independent variable in a regression equation with the primary dependent variable of interest, which in this study is tool diffusion within projects. Similar to the first method, non-respondents are considered to be a linear extension of the latest respondents, and "a trend may be detected across respondents based on relative earliness or lateness to respond" (Lindner, et al., 2001, p. 52). As the resulting regression model in Table 12 does not yield statistically significant results, it is fair to assume that non-respondents do not differ from respondents.

In further support of the findings of these two methods using tool diffusion among projects as the primary variable, I repeated both methods for another primary variable, namely mean performance (defined in Section 5.2.12, p. 128). As before, both methods yield insignificant results (method 1: $F = .556$; Sig. = .458; method 2: $F = .002$; Sig. = .966) using this variable.

In conclusion, based on the two methodologies proposed by Lindner, Murphy, and Briers (2001), the non-response error does not pose a serious threat to the external validity of this study.

Table 12: Linear regression model for Method 2 – 'days to respond'

Descriptive Statistics*

	Mean	Std. Deviation	N
Diffusion within Firms	23.76	12.660	99
Days to respond	8.41	3.423	99

* Test variable: tool diffusion within projects

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.113[a]	.013	.003	12.643	2.101

a. Predictors: (Constant), Days to respond

b. Dependent Variable: Diffusion within Firms

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	201.480	1	201.480	1.260	.264[a]
	Residual	15504.702	97	159.842		
	Total	15706.182	98			

a. Predictors: (Constant), Days to respond

b. Dependent Variable: Diffusion within Projects

4.5 CASE STUDY RESEARCH

4.5.1 Justification

The case study work complements the survey findings as it probes beneath the questionnaire responses that uncovered collective patterns in tool adoption and use, and addresses issues that were not suitable for survey-type research. A case study is a record of an event, the persons involved, and other impacting factors, and often has an institutional focus (Roselle, 1996). Rahim and Baksh (2003a) comprehensively describe the use of case study research techniques specifically in NPD research, justifying its appropriateness in this field of study:

- With case studies one can ask, and answer, in-depth and probing questions, which may not be possible with other methods. It is especially useful for exploring topics when there is not a strong supporting theory, as is the case with NPD tools.

- Case study research is ideally suited to exploratory work. Since the theory relating to tool use in NPD projects is not well established, aspects of this research is very much exploratory in nature.
- Case research is superior to survey methods at answering the ‘how’ and ‘why’ type questions, because it delves more deeply into motivations and actions than structured surveys.
- The case study as a qualitative technique is more suitable for data collection because each participating organisation will have its own peculiarities regarding mode of operation. Such peculiarities are difficult if not impossible to detect clearly from generic questions used in quantitative studies. The latter methodology can record measurements but cannot describe or examine rare events and developments in NPD.
- Case study research has the ability to reveal a deep level of detailed information associated with particular contingencies.

Although the primary research questions had already been formulated prior to the start of the case studies, I added secondary questions as they were revealed during the course of investigation, which is customary in this kind of research (Page & Meyer, 2000).

4.5.2 Research Purpose

The purpose of the case study research was to study various aspects of tool application and use in the context of NPD projects, rather than independent of it as was the case with the preceding survey research. The conceptual models in the previous section suggest that projects have a life of their own and that tools are only one influence on their conduct. Each project therefore constitutes a unique set of praxis, making key aspects of this research discovering if and how practitioners incorporated tools into NPD activity and how tools contributed to its execution. The analyses of the selected cases helped me to verify the individual elements of the research framework as it applies to small high technology firms, and provide deeper insights into each of its elements.

4.5.3 Case Selection

In making the decision of how many cases to include within this part of the research, I considered the main two opposing scholarly views. On the one hand are the classic case study researchers such as Dyer and Wilkins (1991), who tend to focus on comparisons within the same organisational context, while on the other hand, people like Eisenhardt (1989) primarily argue for comparisons across organisational contexts. The classic researchers argue that single case studies generally provide a deeper understanding and richer description of a particular social setting than multiple cases do. With multiple cases, the number of contexts investigated is inversely proportional to the contextual insight gained and the focus is on “surface data rather than deeper social dynamics” (Dyer & Wilkins, 1991, p. 615). The trade-off to be considered is clearly between deep understanding (single case) and the benefits of comparative insights (multiple cases).

Three factors influenced my choice of multiple cases. In the first instance, while it was not the intention with this study to investigate the impact of individual characteristics (e.g. psychological types) or team characteristics (e.g. level of acquaintance, group cohesion, workload sharing) on tool application and use, this study certainly hopes to unveil ‘surface aspects’ of social dynamics in answering the ‘why’ and ‘how’ questions.

The second factor is to be found in the rationale that favours single-case designs, which Yin (2003) summarised as: 1) When a case represents the critical case in testing a well-formulated theory; 2) when the case represents an extreme case or a unique case; 3) the case is the representative or typical case; 4) the case is revelatory; 5) the case is part of a longitudinal study. As none of these rationales is applicable to my research context, it makes sense to use multiple cases.

I derived the third decisive factor from taking into consideration a number of findings from my survey research. Two of the statistically significant determinants of tool adoption are firm size (in terms of the number of staff employed): - larger firms are likely to adopt more tools than smaller firms do; and NPD project size (in terms of the number of team members engaged in the project). Furthermore, a comparison of the relatively small firms in this study with larger firms of past research shows that larger firms tend to follow more formalised and sophisticated NPD processes than smaller firms do. As tool adoption varies among firms of different sizes (which also accounts for different degrees of process sophistication) and project size, it seems important to compare aspects of tool use among firms of different sizes and projects of varying size, which by implication involves multiple cases.

Consequently, I decided to base my case selection, shown in Table 13, both on firm size (in terms of number of staff employed) and project size (as reflected in the size of the core development team) to facilitate inter-case comparisons (identifying both commonalities and differences). For confidentiality reasons the identities of the participating firms and individual participants are not disclosed, hence reference to actual individual company results identifies the firms only as Company A, B, C, D and E. Because of the anonymity of participating firms, I provide detailed contextual information on each of the companies in Table 13 and at the start of each individual case write-up in Chapter 6 to allow for some understanding of the prevailing conditions and circumstances under which the projects were implemented, without compromising the identities of the firms.

I chose the first four cases purposely to fit neatly within the typical small firm context, which is the focus of this study. For comparing tool-use aspects, I included the fifth case as a company representing the larger international firms, with offices in 10 countries, a network of distributors and dealers in another 150 nations, and employing about 800 people around the world. The five cases in this research fall within the observed range of Rahim and Baksh's (2003a) summary of case study research in NPD that shows the number of cases varying from two to nine, and five cases were deemed sufficient for the purpose of theory building. (There is no precise guideline to the number of cases to be included in case study research (Perry, 1998)). This particular choice of cases made it possible to compare aspects of tool application and use among firms and projects of different size. Each case was carefully selected so that it either predicts contrasting results (theoretical replication) or similar results (literal replication) for various aspects of tool application and use, but for predictable reasons (Yin, 2003).

Furthermore, I decided to restrict my cases to hardware projects (which may or may not have embedded software) completed by firms in the South Island of New Zealand. Hence, I did purposive sampling (non-randomly) of five companies and projects in this region that met the various size criteria, were known to be involved in NPD, and were willing to participate in the study. This is good research design in case study research as random case selection can result in not meeting the objectives of the case study (Eisenhardt, 1989). Of the five cases included here, only Case D participated in the initial online survey. Although Table 13 shows the respective tool diffusion rates within the five companies, I was only able to calculate these values at the time of data analysis. Hence, I had no idea if the tool diffusion within firm values would increase with firm size or the size of the core development team.

Results indicated that, for its relative small size, Company A used a disproportionate amount of tools compared to the larger firms in the sample (44 out of a possible 76 = 58%). For the remaining four cases, there is more or less a trend of increasing tool diffusion with firm and project team size, in line with hypotheses $H6a^{det}$ and $H7^{det}$ respectively (see Table 18, p. 118). I did notice that, for the five cases, tool diffusion within firms follows the same pattern as development time (in months). Even though it is logical that the longer a project lasts, the more tools would be used, this particular observation is probably only coincidental, as I could not find statistical support for such a hypothesis, having revisited the survey data.

Table 13: Basis for case selection and case characteristics

Firm size (full-time staff)	6-9	10-19	20-29	40-49	100+
Company	A	B	C	D	E
Core development team / Total involved within firm	4 / 6	4 / 6	12 / 12	4 / 12	35 / 90
Product	Electronic computer security device	Print media wrapping machine	Medical appliance	Gas fire heater	Portable 2-way communica-tions radio
Product category	Consumer	Industrial	Industrial	Consumer	Industrial
Product architecture	Integral	Integral	Modular	Modular	Modular
Tool diffusion within firm according to survey	55%	29%	43%	43%	68%
Development time (months)	24	12	16	20	24
Development cost	> $100k	$60-70k	> $100k	> $100k	$14 million
Innovation strategy	No	No	No	Yes	No
Stage gate process (stages)	No	No	Yes (5)	Yes (5)	Yes (7)
Innovation category	New-to-the-world	New-to-the-firm	New-to-the-world/more innovative	New-to-the-firm/more innovative	Reposition-ing/more innovative
Company age (years)	6-10	6-10	> 10	6-10	> 10
Export % of total sales	> 50%	11-30%	> 50%	1-10%	> 50%
Number of interviews	3	3	3	3	5

4.5.4 Data Gathering Techniques

The case study approach employed in this research primarily used qualitative data, as the main method for data collection was semi-structured interviews. However, to a lesser degree it also used quantitative data that I gathered from the structured online survey and practitioner questionnaires, in particular for the section on tool familiarity. I used four methods for data collection:

1) **Invitation-only online survey**: As a starting point for each case, I asked the project manager to complete the survey (see Section 4.4 p. 72) for a particular project. The information thus obtained (it being exploratory and descriptive in nature) gave me a good overview of the tools that were used in the project, and tool usage patterns.

2) **Project questionnaire**: To obtain more information about the project itself, I also asked the project manager to complete a short project questionnaire (paper) in his/her own time (see Appendix 4). The practice of using written surveys as an additional method of obtaining information is common in case study research (Olson, Walker Jr, Ruekert, & Bonner, 2001).

3) **Interviews**: I was the only investigator and I initially conducted semi-structured interviews with three to five key project team members for each project (see Appendix 5). Three or more interviews were necessary to ensure data validity. An additional step to improve the validity of the questioning process (construct validity) was to carry out expert validation among experienced academic staff that checked on academic content, practicality, and applicability of the issues raised. The interviews covered the areas of tool adoption, tool familiarity, reasons for use, tool application, and users' experiences with tools. Towards the end of each interview, I administered a practitioner questionnaire that I customised according to indicated tool usage (from the online survey) with each participant. Follow-up contacts with the same people gave me the opportunity to discuss interim findings and ensure correctness of recorded results and interpretations. I recorded all of the interviews and had them transcribed by a professional service.

4) **Documentation review**: I gathered and studied NPD project notes, minutes of stage-gate meetings, as well as formal and informal documentation related to the project so I could 1) verify and confirm data obtained from the semi-structured interviews, and 2) obtain additional information that the interviews did not capture. I archived all this information in a secure filing system.

4.5.5 Designing of the Data Gathering Instruments

Appendix 4 lists the questions in the paper questionnaire that I posed to each project manager prior to the interviews. Its purpose was to obtain a detailed understanding and background of each project so I could conduct the interviews from a knowledgeable position. I used the set of primary research questions to develop the questions for the semi-structured interviews and the concluding interview questionnaire. Appendix 5 outlines the format of the semi-structured interviews that I conducted with three to five of the project team members of each project (case). The interview questions reflect the actual line of inquiry I followed, but I did not pose them directly to participants. Essentially these questions only served as reminders to me regarding the information I needed to collect, and why. In some instances, the specific questions also served as prompts in asking questions during the case study interview. However, their main purpose was to keep the investigation on track as data collection proceeded. At the end of each interview, I administered a structured questionnaire (see Appendix 6) to capture some very specific aspects of tool use, and some user characteristics regarding tool use. The focus here was on practitioners and their inclinations towards tools on matters including tool familiarity, thoroughness of use, the reasons why practitioners made tool choices, and tool experiences in general. Prior to conducting this part of the interview, I used the results of the online survey to compile a list of tools used during the project that I presented to each participant.

4.5.6 Preparing for Data Collection: Obtaining Approval

I contacted each of the firms in this study by means of a formal letter (see Appendix 7) in which I explained the purpose of the study and what it would involve. All the participants committed themselves in writing and pledged their full cooperation. Each firm also provided me with the names, designations and contact details of key project team members who were to be interviewed by me. For the first four cases (relatively small firms), I interviewed three prominent team members in order to obtain the broadest possible perspectives and points of view from different key areas (e.g. project management, mechanical engineering, software development, marketing). Three interviews were deemed sufficient for the first four cases, as the size of teams was small and individuals were 'wearing several hats' during project execution. For the fifth case, the larger company, I did five interviews because the core development team was significantly larger than for the first four companies.

4.5.7 Preparing for Data Collection: Project Preparation

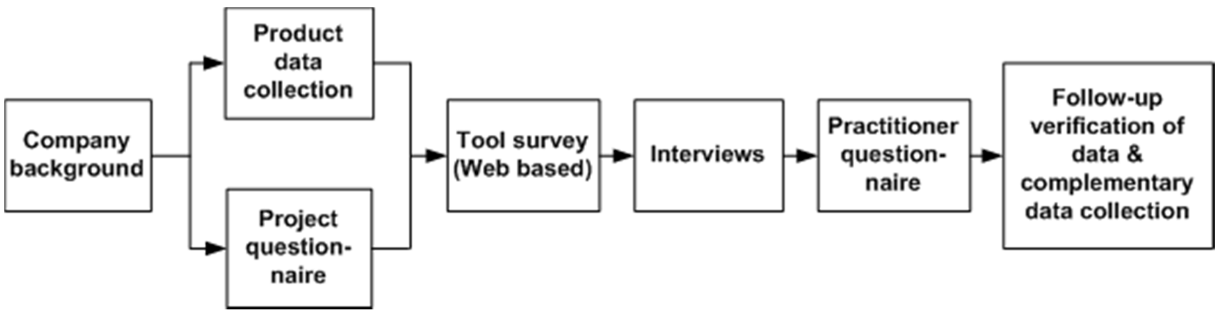
I created a case study project by using the NVivo qualitative software package that assisted me with categorising, sorting, storing, and retrieving of electronic data for analysis. I also created a physical filing system for managing hard copies of documents and physical artifacts, and developed a case study protocol. A case study protocol is "a record (normally a document) that contains the methods, procedures and general rules that will be followed in using instruments of data collection" (Rahim & Baksh, 2003a, p. 32). My case study protocol consisted of the following items:

- An overview of the case study project that covers the background information about the project and the substantive issues being investigated. This statement includes the letter of introduction (see Appendix 7) sent to all the participants.
- The data collection procedures. This section includes the names of the firms to be visited, including key people and their full contact details, a data collection plan, and the expected preparation prior to site visits.
- The interview questionnaire (see Appendix 5) for directing the line of inquiry.
- A guide for the case study report (outline, format for the data, use and presentation of other documentation).

4.5.8 Field Data Collection

The collection of data started in April 2009 and ended in July of the same year. As each case involved interviews with three to five people that also included other data-gathering activities, each case represents multiple visits of several hours at a time. For each case, I established a clear chain of events that can be traced from start to end, depicted schematically in Figure 15.

Figure 15. Data collection chain of events



At the start of each interview, I explained to the participant exactly what format the interview would take and how long it was expected to last. I assured them that all responses were to be treated confidentially and that their privacy was guaranteed. I also explained that they could refuse to answer any of the interview questions. Throughout the project, I collected and stored multiple sources of evidence comprehensively and systematically, anything that was seen as supporting the objective of the research. In addition to recording all interviews, I took written notes during interviews and recorded field notes after each interview. Where necessary I carried out repeat interviews to gather additional data to verify key observations or check a fact.

4.5.9 Data Evaluation and Analysis

According to Rahim and Baksh (2003a) the analysis of case study data is the most difficult in this type of research. They state that while the analysis of such data is not an exact science, there are many ways to analyse and present the qualitative data collected from the case studies. For example, cross-case and within-case tables, flowcharts and diagrams, can be used to complement the case study write-up. Write-up can consist of pure description and the combination of analysis and description (Simon, Sohal, & Brown, 1996), from where final conclusions can be drawn.

Yin (2003), however, recommended a more systematic, three-thronged approach for analysing data. The first step is to decide on a general analytic strategy - to define priorities for what to analyse, and why. He mentioned three basic strategies that researchers can follow: 1) relying on theoretical propositions, 2) setting up a framework based on rival explanations, and 3) developing case descriptions. In conjunction with the research questions, the latter strategy was the most appropriate for structuring the write-up of the five case descriptions (Chapter 6) and the subsequent cross-case analyses (Chapter 7).

The second of Yin's recommendations is using one or more of five specific techniques with the chosen analytic strategy: 1) pattern matching, 2) explanation building, 3) time-series analysis, 4) logic models, and 5) cross-case synthesis. For this study, the first, second and fifth techniques were useful, which Yin (2003, p. 116) defined as follows:

> Pattern matching: "A comparison of empirically based patterns with patterns predicted prior to data collection (or with several alternative predictions)". Internal validity is strengthened by coinciding patterns.

In the context of this study, patterns predicted prior to data collection would be the findings of past research, where available, that stem from the review of the literature, and from the conceptual models I developed in Chapter 3.

> Explanation building: "An analysis of case study data, in narrative form, by building an explanation about the case." To 'explain' a phenomenon is to stipulate a presumed set of causal links about it. Often, the eventual explanation is likely to be a result of a series of iterations, starting with an initial theoretical statement or an initial proposition. The findings of an initial case are then compared against the statement or proposition, revised if

necessary, compared with the next case, and repeated as many times as required.

Cross-case synthesis: "An aggregation of findings across a series of individual studies, for example, creating word tables that display the data from the individual cases according to some uniform framework." The analysis of the entire collection of word tables enables the study to draw cross-case conclusions of observed patterns in tool use.

Table 14 summarises the approach I took in analysing the case study data, which is a very similar path as that taken by other researchers in NPD (Rahim & Baksh, 2003a). As far as possible, I have tried to convey the original context of the data by using quotations from interviews to 'tell the stories' and illustrate my points.

In the final instance, Yin recommended familiarity in using tools such as computer-assisted routines and prepackaged software for searching and indexing databases, but warned at the same time these are only useful if the researchers know what to look for. The qualitative software NVivo enabled me to effectively code all the electronic files (documents, interviews, surveys, field notes, etc.) into 20 categories that are not mutually exclusive.

Table 14: Data evaluation and analysis

Analytic Strategy: With the research questions as basis, I developed a descriptive framework for organising each case study that I used for a) identifying overall patterns that b) ultimately explain various aspects of tool usage.
Steps and purposes: 1) I wrote up five detailed case studies (Chapter 6) in narrative form. Purpose: descriptive and data reduction. 2) I conducted cross-case synthesis using a variety of data displays, including pattern-matching and explanation building techniques where appropriate (Chapter 7). Purpose: exploratory and explanatory. I derived explanations from a series of iterations or revisions of initial statements. 3) I concluded with a number of generalisations of the cases.

Where appropriate, I used within-case and cross-case displays - "spatial formats that present information systematically to users" (Miles & Huberman, 1994, p. 79) - such as tables, matrices and flowcharts for reducing and analysing a significant amount of qualitative data, while constantly looking for opportunities to triangulate the data with company documents and archives in order to increase the reliability of the information.

Once I had written up the detailed case studies, I returned them to each of the 17 participants for comment and amendment. At the same time, I posed additional questions that sprung from the analysis, and included these responses in the final analyses.

4.5.10 Report Preparation

In this study, I deliberately designed the case study to be part of a larger, multi-method study, illustrating in greater depth the ways and experiences of NPD teams, and gaining insights in the patterns that emerged from the survey findings. The final steps were to present the write-up of individual cases in Chapter 6 and the cross-case analysis in Chapter 7.

4.5.11 Quality of Research

Throughout all the major stages of my case study - from research design, data collection, data analysis to case study composition - I observed the four rigour criteria proposed by Yin (2003), using tactics suggested by Gibbert, et al. (2008):

1. 'Construct validity' (pertinent in the data collection phase): - refers to the extent to which a study investigates what it claims to investigate. Steps to enhance this criterion include:

   - The development of a well-considered set of measures: - I carried out expert validation by getting experienced academic staff with industry experience to check on academic content, and practicality and applicability of the issues raised.

   - Establishing a clear chain of events of evidence in progressing from the initial research questions to the final conclusions: - The comprehensive case study protocol I introduced (see Section 4.5.7) ensured this condition was met.

   - Using multiple sources of evidence: - (also referred to as triangulation - the adoption of different angles from which to look at the same phenomenon). In this study, I triangulated the interview findings with other evidence obtained from a multiple of sources, including company contextual data, product data, NPD process diagrams, three different surveys (online quantitative survey, project questionnaire and practitioner questionnaire), tool charts that I prepared from the online survey, several repeat interviews via telephone to clarify uncertain points, as well as field notes.

   - Having key informants review draft case study write-ups: - All 17 participants provided written feedback and confirmation on their case write-ups (see previous section). Furthermore, the fact that I asked my participants what they did in very specific instances, within the context of a very specific project that was completed in the very recent past, asking them about actual events and eventualities, not things in general, lessen the likelihood that they would have strayed from giving responses as they honestly recalled them.

2. ‘Internal validity’ (pertinent in the data analysis phase): - refers to the causal relationships between variables and results. Tactics that I used to enhance internal validity:

    - Formulating a clear research framework: - The research framework that I developed (Figure 9, p. 69) is evidence of this.
    - Pattern matching: - I compared empirically observed patterns with either predicted ones or patterns established in previous research.
    - Explanation building: - is an iterative process that begins with a theoretical statement that is repeatedly refined and revised until a final explanation is derived. This tactic only applies to limited areas of my research.

3. ‘External validity’ or ‘generalisability’: - is the process of establishing the domain to which a study’s findings can be generalised beyond the immediate case study. Ways in which I enhanced external validity include using five cross-case analyses to provide a basis for analytical generalisation, and the provision of a clear rationale for the case study selection (see Section 4.5.3, p. 88).
4. ‘Reliability’ (consistency): - refers to the absence of random error, enabling subsequent researchers to arrive at the same insights if they conduct the study along the same steps again. Ways in which I enhanced reliability include ensuring total transparency throughout all the phases, having carefully documented and clarified my research procedures and case study protocol, and finally through replication by means of putting together a case study database that includes all the case study notes, documents, and narratives that allow for easy retrieval by others.

4.6 LIMITATIONS

As this research involved survey and case study method, I discuss the respective limitations separately.

4.6.1 Survey Limitations

Survey limitations are both of a contextual and a measuring instrument nature. An explanation of the former is given below:

1) Innovation is an activity jointly performed by individuals ideally constituting cross-functional teams. For reasons of simplicity and practicality, the survey instrument only collected data from a leading team member. The survey instructions did ask for the survey to be completed by the person most knowledgeable about the particular project, but no control could be exercised to ensure this was indeed the case. Consequently, the submitted responses may not contain the best information about a particular project as no one person can expect to have complete knowledge of a development project.

2) Innovation tool usage within organisations is inextricably linked to organisation-specific routines. As the unit of study is the product development project, influences that fall outside the direct scope of tool usage received little or no consideration.

3) There is no definitive guide for the study of NPD tools in the specified context. It is possible to associate categories of innovation tools with particular innovation process stages, but as innovation processes are likely to differ from industry to industry, and from company to company, the study of tool use was done using one particular taxonomy which in some cases may be considered as over the top and in other cases not comprehensive enough. Any attempt towards establishing an appropriate and suitable taxonomy will therefore necessarily be subject to criticism.

4) Firms that are relatively more innovative compared to others may have been more inclined to participate in the research. This factor will have no negative effect on determining effective practice – to the contrary, it may strengthen the results, as poor innovators would expectedly have little to contribute to effective innovation practice. However, this factor may skew the results favourably towards better practice when assessing various aspects regarding the general state of innovation tool use in small high technology firms. On the other hand, the tests that I carried out in Section 4.4.8 (p. 84) to determine the impact of the non-response error showed no significant statistical difference in the primary research variable (tool adoption) between respondents and non-respondents, hence all indications are that the impact of this factor is negligible.

Surveys, in general, do have their inherent shortcomings, some of which include:

- Possible ambiguity over the questions asked, low response rates, no control over who actually answers the questions;

- It is not possible to ask in-depth questions to follow up specific questions;
- It is also not possible to cross-check answers with company documents;
- Valuable information that can be gathered from a tour of the workplace or observation is not possible;
- Many of the survey questions use Likert-type scales that record measurements based on participants' perceptions, rather than objective, factual data. In such cases, it is impossible to verify the accuracy of such data, a factor that affects the validity of the measuring instrument.

Knott (2008) highlighted several apparent limitations which are very specific to my type of research - where researchers use list-based tool surveys to capture various aspects and terminology of tool usage. The first problem with this methodology could be that the tools managers used were different from those in questionnaires. Any attempt to list all known tools would be ill fated because of the sheer numbers of tools that exist. It would also be utterly impractical to use large lists due to size and time constraints of surveys. In this research, I addressed the problem by selecting only the seemingly most popular tools in each of the categories of tools I identified, ignoring tools that are not frequently cited in the relevant literature (see Section 4.4 p. 72 for a detailed discussion on this topic). In doing so, I may have excluded any number of legitimate, effective tools that are currently in use among my research sample of NPD firms. This problem is unavoidable and one that any researcher in this field would encounter. The fact that my survey included a far greater number of tools than any previous research, indicates that I have attempted to address this problem as far as possible.

The second associated problem with list surveys is that managers often use tools such as 'project management' and 'brainstorming' but they do not view them as specific tools because they are so generic and widely used. My survey did include some generic tools such as the examples mentioned, and the response rate for these tools indicates that, where appropriate, respondents did acknowledge use of such tools.

The third problem from Knott's (2008) research is where respondents indicated tool use even though they had not used the tool formally, but only to a very limited extent - perhaps just as part of the initial inspiration for an initiative. I overcame this problem by providing respondents with a five-point Likert-type scale in which they could indicate the level of thoroughness of tool use for each individual tool.

The fourth and probably biggest problem identified by Knott (2008) relates to overlapping tool content among tools. As an example, Knott cited the generic similarities among 'quality circles', 'total quality management' and 'six sigma'. The implication is that a user may be using aspects of a particular unlisted tool that are similar to those of a listed tool, and therefore fails to record usage in that area. Obviously, situations such as these contribute to inaccuracies in capturing actual tool usage. A potential solution to this problem is to study categories of tools that serve a broadly similar purpose. In this research, I followed a dual approach in measuring the extent of individual tool usage as well as indicating levels of tool usage among categories of tools. Section 2.2.5 (p. 21) details the procedure I followed to achieve this.

4.6.2 Case Study Limitations

As is the case for any research instrument, the case study methodology also has its limitations. Rahim and Baksh (2003a, p. 34) summarised the limitations from an NPD research perspective:

- "The case study method suffers from a lack of rigour, ad hoc theorising, a general neglect of the testing of data and the use of subjective judgements during data collection stages – all can render constructs invalid." Yin (2003) suggested the way to instil rigour is by strictly following systematic procedures (Sections 4.5.7 and 4.5.8 attest how I adhered to this principle) and not allowing equivocal evidence or biased views to influence the direction of the findings and conclusions. With regard to the latter, Langley (1989, p. 599) added that "data analysis relies greatly on the perceptions of one researcher", which I tried to alleviate, at least partially, by providing plenty of supportive examples and by using quotations from interviews to illustrate my points.
- It is not always an efficient method, as many visits may be needed to fully achieve the research goals. Yin (2003) proposed several ways for shortening case studies and avoiding lengthy narratives - the most significant is probably careful planning before conducting the case study, which is clearly evident from the way I describe it in this chapter, e.g. thoroughly designed case study protocol; systematic choice of cases/respondents; well-designed interview and questionnaire instruments.
- Impacting research effectiveness and results are the human factors such as personality, experience, training, and intellect of the researcher. I trust the five years of industry

experience I gained in product development prior to my academic career enhanced my understanding and interpretation of data.

- Case study research can result in too much or too little information. Once again, careful planning prior to the start of the case study minimised this effect.
- It can happen that "the full meaning of the data may not be fully grasped resulting in temporary conditions be taken to represent normal ones" (Rahim & Baksh, 2003a, p. 34). My iterative approach, combined with tri-angulation of data across cases, helped me avoid this potential weakness. Not only did I interview three actors per case, but I also structured the interviews carefully, making sure they were about specifics. In all instances, I went back to the 17 participants, presented them with the first analysis, received their feedback, incorporated that into the second version and, where necessary, followed up again on specific issues to ensure the best possible interpretation of data.
- There could be the temptation to build theory that tries to capture everything. Having had a pre-determined and well-defined set of research questions helped focus me on a limited, specific set of issues. Subsequent reflections and discussions of observed phenomena with my research supervisor also ensured I kept my focus.
- Finally, Rahim and Baksh urged researchers to be aware that informants might sometimes not give the whole picture of the subject studied in fear of possible negative repercussions. I believe the fact that I ensured the respondents' anonymities sufficiently dealt with this problem.

Yin (2003) lists another common concern with case studies, namely that they provide little basis for scientific generalisation. His answer to this is that case studies, like experiments, are generalisable to theoretical propositions and not to populations or universes. As such the results of my case study research should be viewed in this context, with any claims made not relating to any particular population (e.g. small high technology firms).

A specific interview-based case research limitation of my study was the reliance on actors' interpreted accounts of events one or more years after the events took place. As a result two inevitable consequences were the collection of subjective data, and actors' potential loss in recollection ability of events. My attempt to minimise these limitations was to interview three or more actors per case.

5 SURVEY ANALYSIS AND FINDINGS

In the previous chapter, I presented a detailed discussion regarding selection of research measures and questionnaire development. In this chapter, using the organising framework of Figure 2 (page 13), I present the empirical results of the thesis. In analysing the survey data I used both descriptive methods and inferential statistics (using SPSS 17.0) such as bivariate methods of association, testing in excess of 20 hypotheses, and parametric methods such as cluster analysis and non-parametric exploratory factor analysis. Where appropriate, I restate each hypothesis and contrast my findings against the literature discussed in Chapter 2.

5.1 EXPLORING DATA

5.1.1 Cleaning the Data File

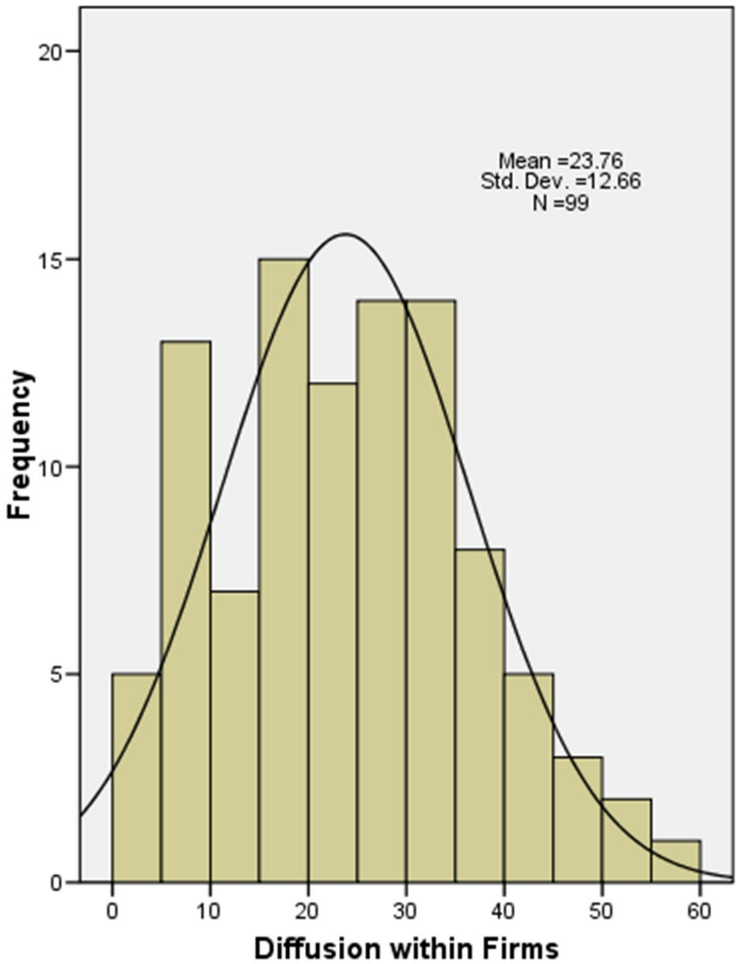
The first step in exploring the data was to look for any obvious incorrectly entered data. Two such cases were found (the respondents ticked all the tools) and removed, reducing the sample to 110 cases. The next step was to look for cases with incomplete data. Since this possibility was eliminated by the nature of response selection and automated checks of the Web survey software, it is fair to assume that all data were entered correctly. The final step in cleaning the data was to quantify the shape of the tool adoption distribution and to look for any outliers. This was accomplished by calculating the output statistics with SPSS (see Table 15) and by drawing histograms and boxplots of the tool adoption frequency distribution.

Table 15. SPSS output statistics for tool diffusion within firms

N	Valid	99
	Missing	0
Mean		23.76
Std. Error of Mean		1.272
Median		24.00
Mode		7
Std. Deviation		12.660
Variance		160.267
Skewness		0.311
Std. Error of Skewness		0.243
Kurtosis		-0.352
Std. Error of Kurtosis		0.481
Range		57
Minimum		3
Maximum		60

A total of eleven outliers were identified and removed from the dataset, resulting in a final dataset consisting of 99 cases. Figure 16 shows the resulting frequency distribution of tool diffusion within firms.

Figure 16. Histogram of tool diffusion within firms (cleaned data)



5.1.2 Testing the Assumptions of Parametric Data

The data analysis in this study involves the use of both parametric and non-parametric tests. For the former, I tested the final dataset against the four assumptions of parametric tests (Field, 2005) to ensure the validity of such tests:

Assumption 1: Normally distributed data

The assumption here is that the data are from a normally distributed population. One acceptable, but less accurate method for asserting this assumption, is the so-called 'eyeball' test. If the sample data (using a histogram) look roughly normal, the researcher assumes that the population is also. Based on this visual test (see Figure 16) it appears that the sample distribution, and hence the population distribution, is indeed normally distributed. A better method than passing subjective judgment of sample normality (the eyeball method), is the Kolmogorov-Smirnov test which is especially accurate for smaller samples such as in this study. The output of this test delivers $D(99) = .060$ with $p > .05$ ($p = .200$), which means that the distribution of the sample is not significantly different from a normal distribution.

Other methods for determining normality include testing the values of skewness and kurtosis, which should both be zero in a normal distribution. As can be seen from Table 15 (the corresponding statistics of Figure 16), neither is zero.

The positive value of skewness (0.311) indicates a slight pile-up of scores on the left of the distribution. When the corresponding z score for skewness is calculated (Skewness / Std. Error of Skewness), its value of 1.28 is significantly smaller than 2.58 (the z score at $p < .01$ for small samples), which is an indication of very insignificant positive skew. With regard to kurtosis, the negative value of -0.352 indicates a flat distribution. Similar to skewness, though, its corresponding z score of 0.73 is far less than 2.58, which is a clear indication of insignificant kurtosis at $p < .01$. Based on these tests it seems reasonable to assume that the sample data are from a normally distributed population.

Assumption 2: Homogeneity of variance

Homogeneity of variance means that the spread of scores of the variable under consideration remains the same at different levels of the variables. The corresponding test is the Levene test, yielding $F(1, 97) = 0.218$, 0.642, $p > 0.05$, which delivers a non-significant result. I therefore accept the null hypothesis that the differences between the variances are not significantly different.

Assumption 3: Interval data

This assumption requires that all data should be measured at least at the interval level, which is not the case in this research. My survey mostly measures abstract perceptions of participants using ordinal scales, but still the calculated means have acceptable legitimacy because of my large number of responses (99) whereby the inaccuracies caused by ordinal data are cancelled out by an averaging effect (Page & Meyer, 2000). Hence, my resulting accumulated ordinal scales are regarded as continuous interval variables (a common practice in this type of research) which mean that assumption 3 is met.

Assumption 4: Independence

This assumption is that data from different participants are independent. When collecting the data for this research, the behaviour of one participant definitely did not influence the behaviour of another, so this assumption is also met.

Clearly all the required assumptions of parametric tests have been met, which implies that all the statistical procedures used in this research are valid.

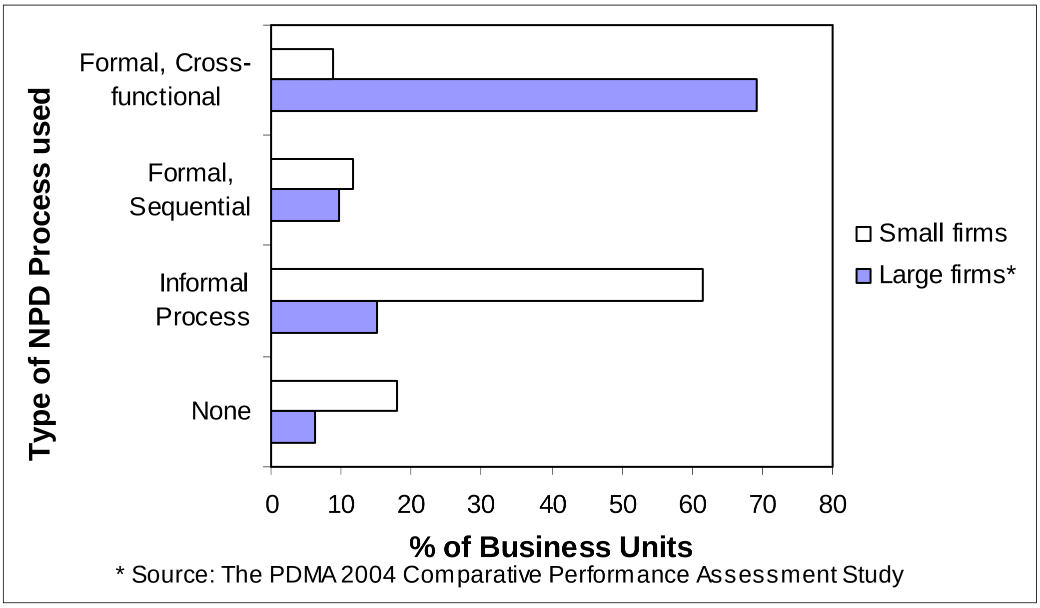
5.2 Analysis and Discussion

Before answering the investigative questions that relate to the survey research, I first investigate the prevailing conditions regarding NPD process and innovation strategy in my sample of firms, as an understanding of these moderating variables will inform the interpretation of survey data at the project level.

5.2.1 NPD Process and Innovation Strategy

It seems reasonable to expect that firms regularly partaking in NPD would have more deliberate and sophisticated processes in place than firms that do so infrequently, or firms approaching NPD in a less formal manner. Disappointingly, but not against expectation (Section 2.5.1, p. 40), the latter approach seems to be prevalent for most of the firms in the current research. As can be seen from Figure 17, 16.2% of firms report that they follow no standard approach to NPD, while another 61.6% of firms have no formally documented processes in place, although they claim to follow clearly understood paths of the tasks required to develop new products.

Figure 17. Type of product development process used



Only 22.2% of firms in the study appear to have formally documented and sophisticated processes in place, which suggests that approximately 80% of firms have no formalised NPD processes. Figure 17 furthermore shows that the findings for small firms differ significantly from those of larger American firms (Adams, 2004) of which the majority (in excess of 80%) have formal NPD processes in place. Corresponding figures for Sweden (Rundquist & Chibba, 2004) and Malaysia (Al Shalabi & Rundquist, 2009) are 71% and 58%, respectively.

Another indication of formalised approach to NPD is whether formal innovation or NPD strategies guide firms' NPD efforts. As expected for smaller firms, I found this was not the case for two thirds of the NPD projects that formed part of this study. The PDMA 2004 Comparative Performance Assessment Study (Adams, 2004) found that larger firms fare much better, where 74% of firms responded in the affirmative for 80% of their projects. Corresponding figures for Sweden (Rundquist & Chibba, 2004) and Malaysia (Al Shalabi & Rundquist, 2009) are 73.3% and 76%, respectively.

Later in this chapter, I investigate the impact of process sophistication and the presence of innovation strategy on tool adoption and use, and aspects of NPD performance. Having some understanding of the processes and strategies that underlie the projects in this research, in the sections that follow I continue to investigate the various aspects of tool usage among small high technology firms.

5.2.2 Relative Importance of NPD Areas

The survey first prompted managers to indicate how much consideration they have given to each of the 12 NPD perspectives in the particular projects under review. Their perceptions were recorded on a 5-point Likert-type scale, with 1 = 'very little consideration' and 5 = 'very much consideration'. Their responses in Table 16 show which aspects of NPD they generally value most, and which least. The four most highly rated considerations with mean values above 4 (> 75%) are, as expected, marketing and market research, creativity & problem solving, engineering & design, and manufacturing. The next 'cluster of importance' has importance ratings between 65% and 75% and consists of project finance, strategy, and decision-making (mean rating scale values between 4 and 3.5). Of lesser importance are the bottom five categories in Table 16 with mean values less than 3.5 (< 55%). By themselves these are interesting results as they clearly show where teams' priorities lie, but of more interest is the observation that for only four of the categories - project finance, general management, information management, and team support (shown in bold) - the importance ratings were significantly and positively correlated with tool diffusion in those categories. When it comes to applying tools in these areas, respondents apparently are ‘putting their money where their mouths are’. The implication for the other insignificant correlations, for example ‘strategy’, is that there is no significant difference between the number of strategy tools used by a manager who rates the importance of strategy in NPD low, compared to one who rates it more important. It is as if managers are saying one thing, yet not following up on it with regard to corresponding tool adoption.

Table 16. Relative importance of NPD areas and tool diffusion within those areas

NPD perspective / Tool category	Mean Values (Respondents' Importance Ratings)		R†	Significance	N
Marketing/Market Research	4.57	>75%	-.054	.318	80
Creativity & problem solving	4.15		.006	.477	83
Engineering & Design	4.09		.086	.207	91
Manufacturing	4.04		-.047	.382	43
Project Finance	3.91	65% - 75%	.294**	.005	76
Strategy	3.86		.078	.247	79
Decision making	3.64		.073	.325	41
Learning & Review	3.19	< 55%	.092	.244	62
General management	3.12		.274**	.006	83
Information management	3.12		.237*	.040	56
Risk management	2.98		.132	.236	32
Team support	2.95		.309**	.007	62

† *Pearson's correlation coefficient* *p<.05 **p<.01

5.2.3 Patterns of Tool Adoption within Projects

Testing for differences in tool adoption between different types of innovation projects

H1^{adopt}: Tool diffusion rates within projects are not dependent on the type of innovation project

Against expectation, I found at the 95% confidence level that the null hypothesis is accepted (F = 1.074, Sig. = .346 for a one-way ANOVA). There appears to be no significant difference in the number of tools used for incremental, more innovative, and radical innovation projects. This finding is in line with the empirical study conducted among bigger firms (Tidd & Bodley, 2002, p. 135) that found that, for the firms in their sample, “the majority of the methods and techniques reviewed are equally applicable to high and low novelty projects” (in this context low novelty equates to NPD projects of an incremental innovation nature, and high novelty to more radical-type projects).

Testing for differences in tool adoption between consumer and industrial products

> *$H2^{adopt}$: Tool diffusion rates within industrial NPD projects are not different from tool diffusion rates within consumer NPD projects*

Contrary to Nijssen and Lieshout's (1995) proposition (p. 45) , a one-way ANOVA test accepts the null hypothesis (F = .184, Sig. = .669), indicating that there is no significant difference in the number of tools used in industrial (N = 60) and consumer (N = 39) NPD projects. This result is confirmed by a simple comparison of the diffusion within project means and standard deviations for industrial (24.2, 12.77) and consumer (23.08, 12.61) products. A possible explanation for this contradictory finding could be in the huge difference in the scope and number of tools considered by the two studies. Nijssen and Lieshout's study involved 23 tools (as opposed to my study's 76) of which many have a customer-involvement component that they say is where industrial NPD is more active than consumer NPD. If this is indeed the case, in this study the net effect is lessened to an insignificant level because of the presence of a greater number of tools from a broader spectrum of tool functionality. I furthermore verified that there was no difference whatsoever between the two types of projects with regard to types of tools used. It is worth mentioning that Nijssen and Lieshout's qualitative study was done at the firm level while in this study *$H2^{adopt}$* was tested at the project level. As the latter case involves quantitative hypothesis testing at the more specific level (project vs firm) than Nijssen and Lieshout's study, one can assume it is more accurate. Based on these findings, I do not distinguish between consumer and industrial projects in this research.

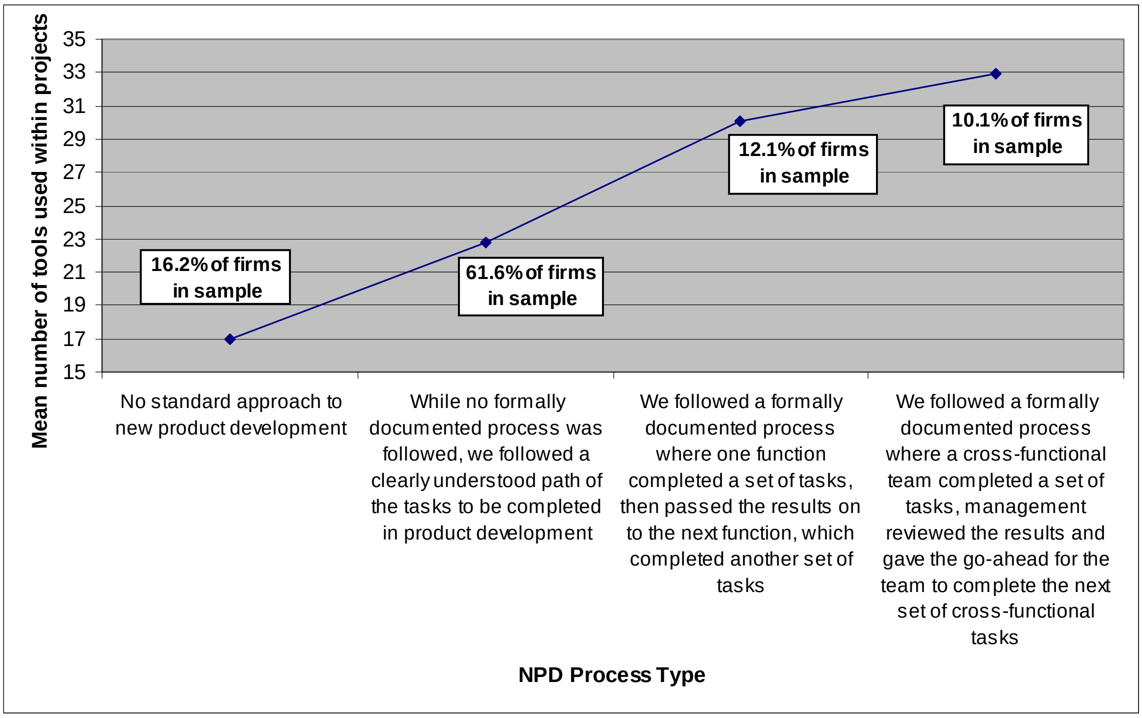
Testing for differences in tool adoption between different types of NPD processes

> *$H3^{adopt}$: Tool diffusion rates within projects are not dependent on the type of NPD process*

While tool diffusion within projects appears not to be related to project type, it certainly does seem so for process type. From the results of a one-way ANOVA I reject the null hypothesis (F = 13.618, Sig. = .000). This finding is supported by Figure 18 that shows a significant increase in mean tool diffusion rates from 16.94 to 32.90 (out of a possible 76) with increasing level of NPD process sophistication. From this, a clear pattern in tool application emerges - the more a firm structures and formalises its NPD process, the more NPD tools they are likely to deploy in their projects.

Disappointingly, from a tool proponent perspective, the results show that the majority of firms (61.6% + 16.2% = 77.8%) in the sample only operate at the 30% and lower diffusion rates. (The mean diffusion rate is 31.3% (23.76 out of 76 tools), which is remarkably similar to Nijssen and Lieshout's (1995) corresponding figure of 30%. Bear in mind the 15-year time difference between the two studies, though.)

Figure 18. Mean tool diffusion within projects vs NPD process type

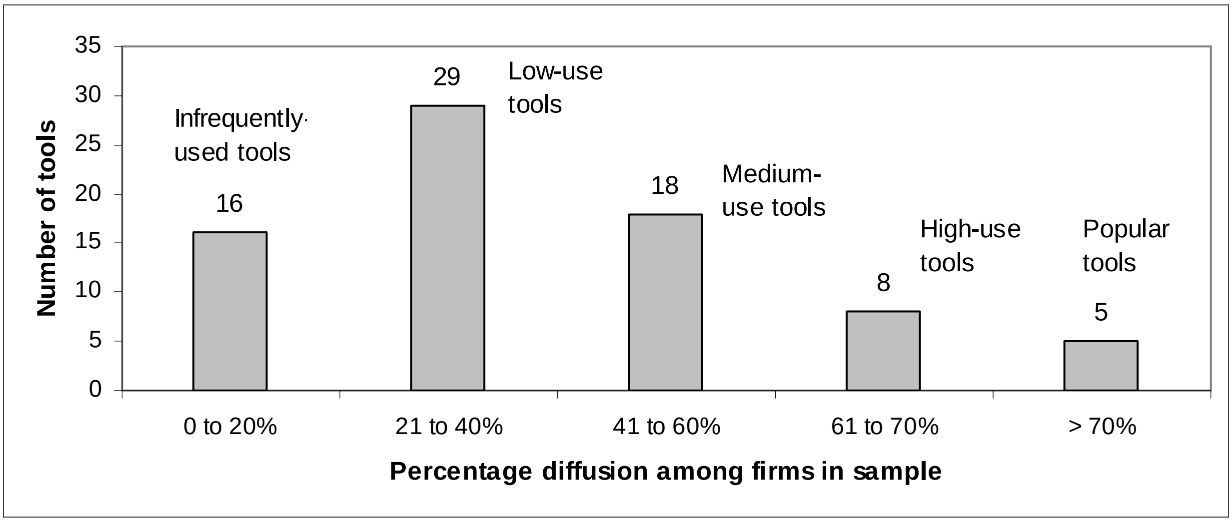


5.2.4 Patterns of Tool Adoption (Tool Diffusion among Firms)

Figure 19 indicates the diffusion spread of the 76 tools in this study among the sample firms in the current study, while Table 17 lists the tools belonging to each of these categories in order of rank. The first group or category of 16 tools, which I term 'infrequently used tools', is used by 20% or less of firms in the present sample. The next three categories are 'low-use tools', 'medium-use tools', and 'high-use tools'. These categories respectively have 29, 18, and 8 tools. The final category, 'popular tools', includes only five tools that are being used by more than 70% of firms in the sample. They are 'brainstorming', 'competitor analysis', 'sales forecast', 'project management' and 'design mock-up'.

The highest mean rate of usage among the 76 NPD tools was achieved by 'brainstorming' (80% diffusion among firms). In similar studies among larger firms (Araujo, et al., 1996) and (Nijssen & Lieshout, 1995), the brainstorming tool also came top of a list of 32 and 11 tools respectively. The reason for this is that brainstorming is probably one of the easiest tools to use, one that is also widely used in areas other than NPD. Respondents also indicated very thorough use of this tool, with an average score of 3.89 on the 5-point Likert-type scale (see Figure 22).

Figure 19. Tool diffusion among firms



As the current study involves a far greater number of tools than any single piece of past research, it is not possible to make one-on-one comparisons with past research for all 76 tools. Table 17 shows that, for those tools for which comparative data among bigger firms exist (shown in brackets), very similar diffusion trends were obtained in this research for tools in the medium, high, and popular categories. However, for several lower-penetration and arguably more complex tools such as 'TRIZ', 'fault-tree analysis', 'morphological analysis', 'conjoint analysis', 'design for six sigma', 'design for X', 'failure mode and effects analysis', 'value analysis/value engineering', and 'benchmarking', smaller firms seem to have lower adoption rates than their bigger counterparts by noticeable margins. It should be borne in mind, however, that the data of the UK (Araujo, et al., 1996) and Netherlands' (Nijssen & Lieshout, 1995) studies are not current, and usage patterns may have changed significantly since the research was carried out.

Another important consideration is that the comparative usage rates shown for Adams' study (2004) in Table 17 are for 'The Best' performers (Adams distinguishes between 'The Best' performers - those companies that use more of all tools - and 'the Rest'). With these considerations in mind, it seems reasonable to deduct that smaller firms tend to shy away from using tools of a more elaborate or complex nature.

A visual comparison of functional tool (Figure 20) and support tool (Figure 21) diffusion rates among firms clearly indicates that smaller firms generally favour the former to the latter. Other than for manufacturing tools, all five of the other functional tool categories include several tools with diffusion rates of higher than 40%.

Table 17. Tool diffusion among small firms

5 Popular tools adopted by more than 70% of firms in sample	
Design Mock-up: 72% (59[1])	Competitor Analysis: 76% (62[1])
Project Management: 73% (77[4]65[5])	Brainstorming: 80% (88[1]61[2]60[4]88[3])
Sales Forecast: 74%	
8 High-use tools adopted by 61 to 70% of firms in sample	
Financial Analysis: 61% (68-79[7])	Marketing Plan: 63%
Business Case: 62%	Cash Flow Forecast: 64%
Design Review Meetings: 63% (92[1])	Computer-Aided Design: 67% (79[4]63[5])
Alpha Prototype: 63% (58[5]63-79[7])	Intellectual Property Protection: 68%
18 Medium-use tools adopted by 41 to 60% of firms in sample	
Change Control System: 41%	Limited Roll-out/Test Marketing: 51% (17[4]26[5]42[6])
» **Cross-Functional Teams**: 42% (65[4])	Needs Analysis: 52% (36[1]17[5])
Checklists: 43%	In-Market Testing: 52% (60[2]34[3])
Total Quality Management: 45%	Customer Satisfaction Tracking: 52%
Scenario Planning: 46% (21-26[7])	Concept Testing: 53% (61[2]43[4]39[5]26[6])
Workflow: 46%	Concept Statement: 54%
Computer-Aided Engineering: 49% (21-37[7])	Beta Prototype: 55%
Rapid Prototyping: 51% (53[1]50[5]))	Collaborative Product Development: 58% (43[4])
» **Beta-testing**: 51% (64[5])	Feasibility Study: 58%
29 Low-use tools adopted by 21 to 40% of firms in sample	
Decision Screens: 21%	Quality Function Deployment: 34% (30[1]17[2]42[4]38[5]43[3]9[6]34-47[7])
Statistical Process Control Charts: 22% (45[1])	Process Flow Diagram: 34%
Roadmapping: 24%	Post-Launch Review: 34%
» **Design for Six Sigma**: 24% (40[4] 31[5])	Post-Project Review: 34%
PESTE Analysis: 24%	Product Life Cycle: 35% (39[2]8[6])
» **Design for X: DFX**: 27% (37[4]49[5]63[7])	Lead User: 36% (40[5])
Configuration Management System: 28% (37[5])	» **Focus Group**: 36% (38[2]38[5]51[3]68[6]37-52[7])
Risk Assessment Matrix: 28%	» **Engineering Document Management System**: 36% (67[5])
» **Gamma Prototype**: 29% (42[5])	» **Project Intranet**: 36% (47[5])
Portfolio Analysis: 29%	» **Benchmarking**: 37% (59[1]58[4]64[3])
» **Failure Mode Effects Analysis**: 29% (70[1] 58[4]48[5]55[3])	» **Voice-of-the-Customer**: 38% (55[5])
» **Tele/Video Conferencing**: 29% (68[5])	» **Design of Experiments**: 39% (28[1]51[4]55[3])
» **Value Analysis/Value Engineering**: 30% (58[1] 43[4]35[5])	Knowledge Management: 40% (57[4]30[5])
Stage-gates: 30%	Teambuilding: 40% (34[5])
Computer Aided Manufacturing: 33%	
16 Infrequently-used tools adopted by 20% or less of firms in sample	
Malcolm Baldridge Awards Framework: 11%	Diffusion Models: 16%
Synectics: 13% (10[2]8[6])	» **Morphological Analysis**: 16% (29[2])
» **TRIZ**: 13% (28[4])	Prediction Models: 16%
Real Options Theory: 13%	» **Conjoint Analysis**: 17% (17[2], 40[4]37[3]15[6])
Expert Systems: 14%	» **Ethnography**: 18% (39[5])
Delphi Method: 15% (6[2]9[6])	Porter's 5 Forces: 19%
» **Fault Tree Analysis**: 15% (26[1])	Computer Integrated Manufacturing: 19%
Discrete Choice: 16%	Selection Criteria: 19%
1: (Araujo, et al., 1996) 2: (Nijssen & Lieshout, 1995) 3: (Chai & Xin, 2006) 4: (Yeh, et al., 2008b) 5: (Adams, 2004) 'Best performers' 6: (Mahajan & Wind, 1992) 7: (Tidd & Bodley, 2002)	

Tool diffusion in the Manufacturing category is relatively low as small firms often outsource the manufacturing activity - hence the application of tools may not show up in this research. Tools with lower than 40% diffusion rates are other obvious opportunity areas where significant improvements can potentially be made - especially those tools for which the diffusion rates are significantly less than in bigger firms.

Figure 20. 'Functional tool' diffusion among firms

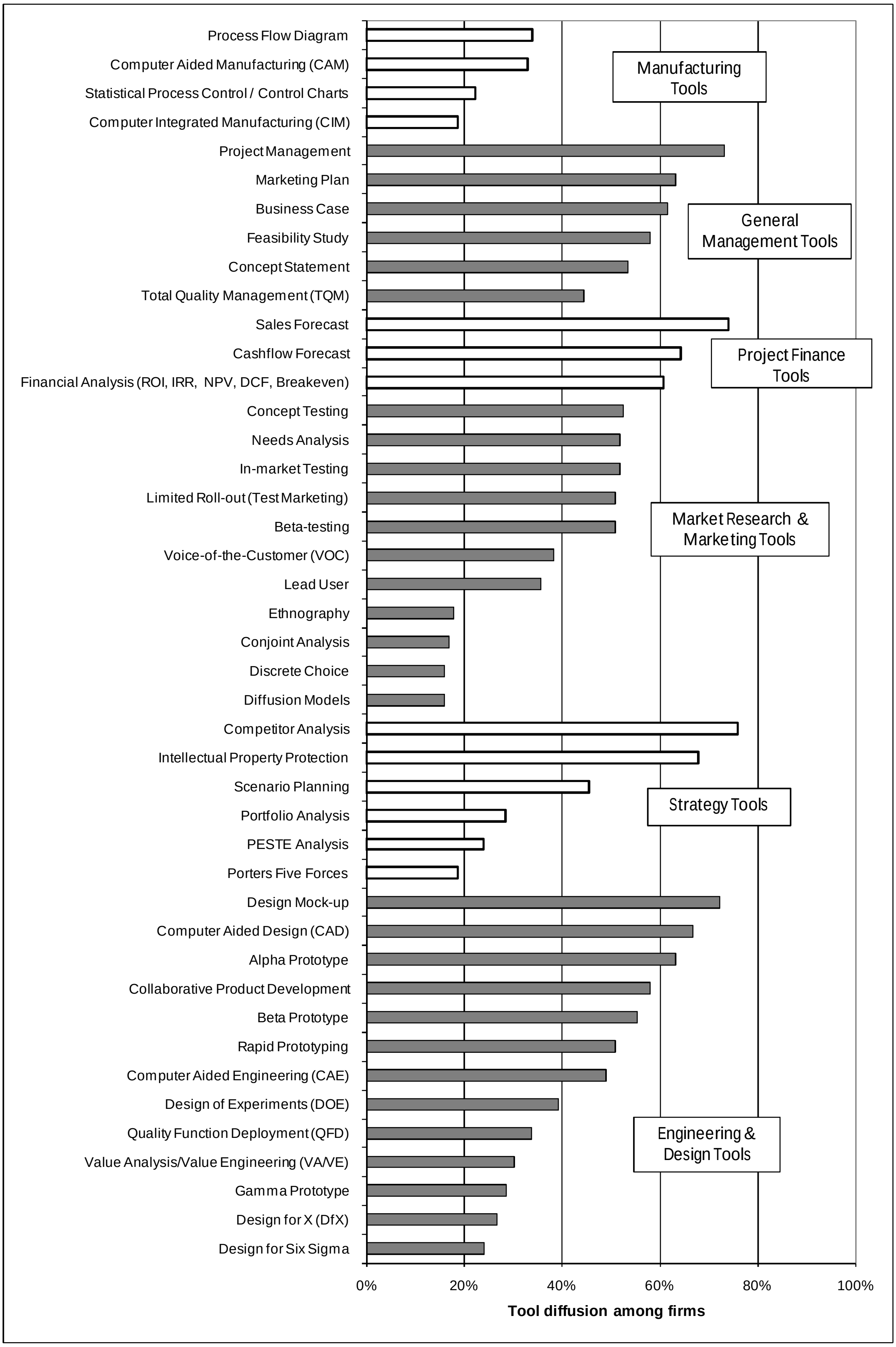
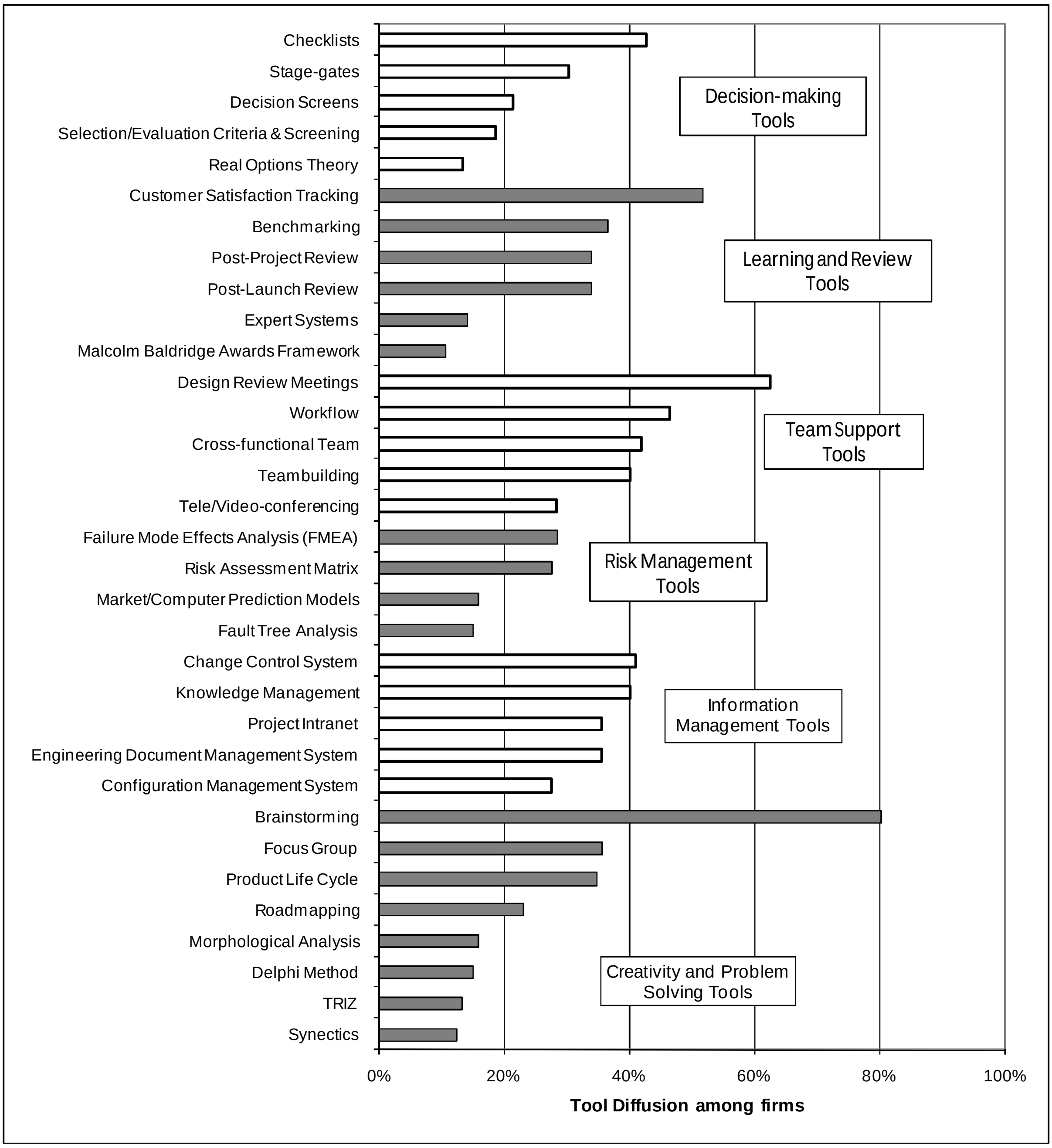


Figure 21. 'Support tool' diffusion among firms



In the six support tool categories only 'brainstorming', 'design review meetings' and 'customer satisfaction tracking' have diffusion rates of 50% or higher. Smaller firms are well advised to critically evaluate the use of support tools and increase their uptake where appropriate. Specific support tools where small firms significantly lag bigger firms are: 'benchmarking', 'cross-functional teams', 'failure mode effects analysis', 'fault tree analysis', 'project intranet', engineering document management system', and 'morphological analysis'.

Several powerful tools such as 'TRIZ', 'Delphi method', 'fault tree analysis', 'discrete choice', 'morphological analysis', 'conjoint analysis', and 'ethnography' are not popular among the present sample. Less than a fifth of firms indicate making use of 'selection criteria', while only 30% of participating firms use 'stage-gates' in their NPD processes. These observations correspond with the 80% of managers in the survey who indicate that they neither had a standard approach to NPD nor followed a formally documented NPD process for the project under consideration.

5.2.5 Thoroughness of Tool Use

$H1^{thor}$: Thoroughness levels of tool application are independent of project type/complexity

A close examination of the tools in Table 17 reveals that the 31 tools with the highest diffusion rates (the top three categories) also appear to be used in a more thorough manner than tools with lesser diffusion rates. As can be seen from Figure 22, thoroughness levels in tool application vary considerably from 1.33 out of 5 (Malcolm Baldridge Awards Framework) to 4.19 for 'beta prototype', also indicating that the majority of tools are not used to their full potential. It also seems fair to deduct that, generally speaking, the more popular tools are applied more thoroughly than less popular tools.

A one-way ANOVA testing of the means found no significant differences among the mean thoroughness levels among incremental, more innovative, and radical types of projects (F = 2.196; Sig. = .142). I thus accept the null hypothesis and the somewhat unexpected finding that project teams in small firms would not necessarily use tools more thoroughly when engaged in relatively more complex projects.

5.2.6 Determinants of Tool Adoption

$H1^{det}$: The level of communication between departments is positively associated with the level of tool adoption in projects

$H2^{det}$: Former NPD tool users are more likely to adopt new NPD tools in projects

$H3^{det}$: The level of top management involvement with the NPD process is positively associated with the level of tool adoption in projects

$H4^{det}$: A higher level of involvement of all the firm's departments is positively associated with the level of tool adoption in projects

$H5^{det}$: An NPD strategy focusing more on turning out many new products is positively associated with the level of tool adoption in projects

H6a^{det}: Firm size, with regard to the number of full-time staff, is positively associated with the adoption of NPD tools in projects

H6b^{det}: Firm size, with regard to the firm's annual turnover, is positively associated with the adoption/application of NPD tools in projects

H7^{det}: The size of the NPD team is positively associated with the level of tool adoption in projects

H8^{det}: The number of stages within the NPD process is positively associated with the level of tool adoption in projects

Within the context of projects, I make the assumption that when a tool is adopted, the intention is to use/apply it. Based on past research in this area (Chai & Xin, 2006; Nijssen & Frambach, 2000; Thia, et al., 2005; Tidd & Bodley, 2002), and appropriate to questionnaire research at the project level, I included eight potential determinants in this study for which I proposed and tested corresponding hypotheses. The results of the regression analysis performed to test my hypotheses are shown in Table 18. The adjusted R^2-value of .298 suggests that the model that underlies the total set of hypotheses, has a good or adequate overall fit (29.8% of the variation in the level of adoption of NPD tools is accounted for by the model). Only four hypotheses in my model are supported by the survey results at the 95% confidence level. They are H4^{det} (the number of departments involved), H6a^{det} (firm size in terms of the number of full-time staff employed), H7^{det} (the size of NPD teams), and H8^{det} (the number of NPD stages in the NPD process).

The insignificant negative effects of communication level among departments (H1^{det}), former use of tools (H2^{det}), top management involvement (H3^{det}), and a focus on turning out new products (H5^{det}) on the level of adoption initially seems puzzling, especially as past research turned out significant effects for these variables (Chai & Xin, 2006; Nijssen & Frambach, 2000; Rigby, 2001b). A possible explanation for some of these anomalies is the exceptional small firm size in this research. As pointed out in the literature review (Section 2.4.1, p. 37), small firms may not necessarily have different 'departments' and their focus on turning out new products is one that exists by default. Hence, these variables hold little meaning in the context of this research. The concept of 'top management' often does not apply in small firms, especially in very small firms where the owner/manager is part of a small NPD project team that makes out the whole business. In this context, the observed insignificant negative association between 'top management involvement' and tool adoption may be contributed to possible negative influences of the dominant owner/manager (Section 2.4.1, p. 37).

Figure 22. Mean thoroughness of tool usage

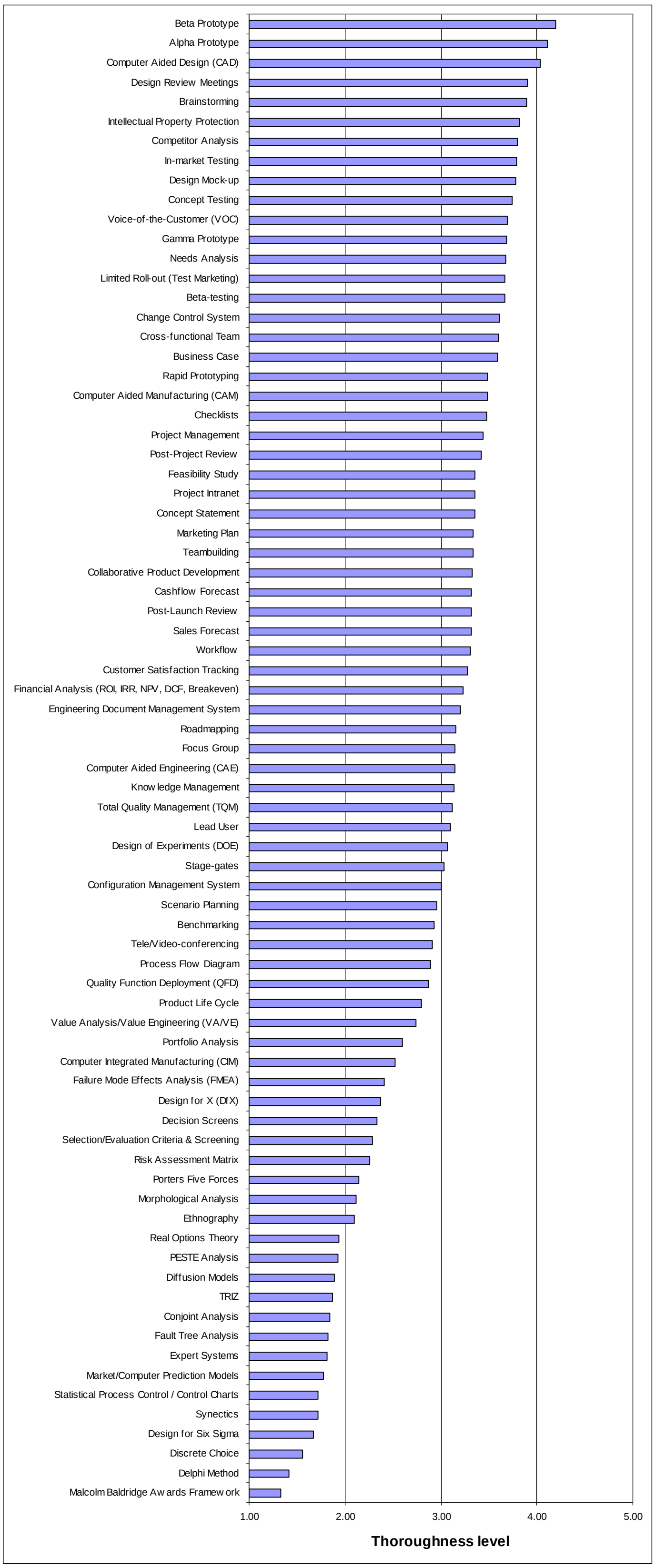


Table 18. Regression results on the determinants of the adoption of NPD tools

(Dependent variable: level of adoption of NPD tools)

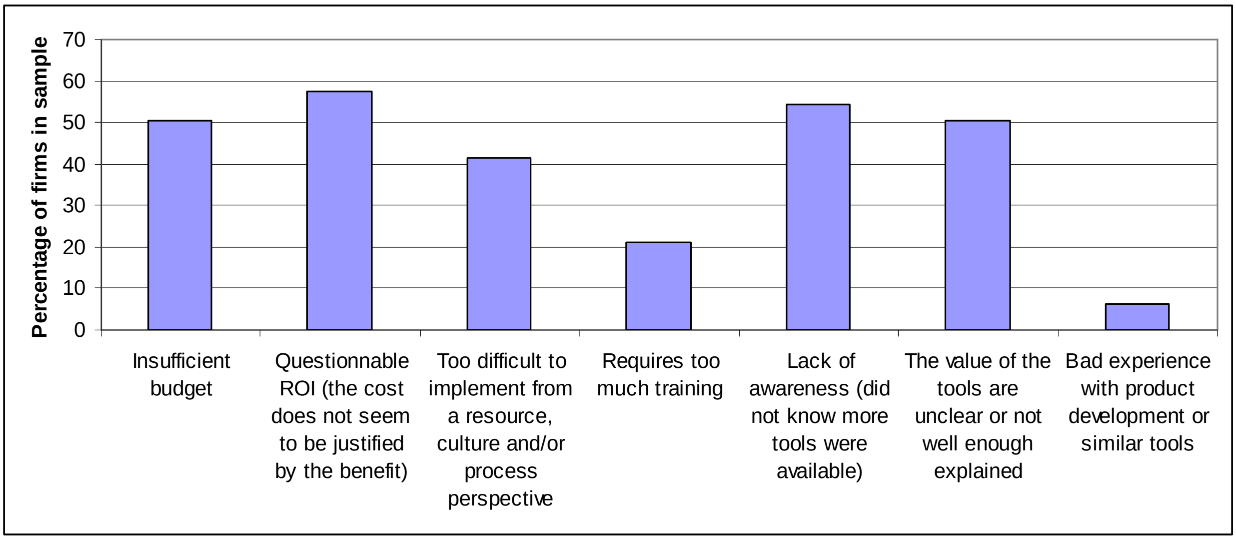
Independent Variable	Hypothesis	Beta	T	Probability T
Communication between departments	$H1^{det}$	-.178	-1.581	.117
Former use of NPD tools	$H2^{det}$	-.019	-.209	.835
Top management involvement	$H3^{det}$	-.092	-.984	.328
Level of involvement from different departments ✓	$\mathbf{H4^{det}}$	**.303**	**2.872**	**.005**
NPD strategy focused on turning out many new products	$H5^{det}$	-.055	-.599	.551
Firm size (number of full-time staff) ✓	$\mathbf{H6a^{det}}$	**.780**	**1.643**	**.052**
Firm size (annual turnover)	$H6b^{det}$	.033	.339	.735
Team size ✓	$\mathbf{H7^{det}}$	**.297**	**3.156**	**.002**
Number of stages within NPD process ✓	$\mathbf{H8^{det}}$	**.363**	**4.192**	**.000**
F = 5.627 Significant F = .000 R^2 = .602 Adj. R^2 = .298 N = 99				
✓ Significant factors at the 95% confidence level				

Overall, it seems that three main factors are associated with higher adoption rates of NPD tools in projects among smaller firms: 1) the number of people involved in NPD ($H6a^{det}$ and $H7^{det}$); 2) a more collaborative approach to NPD ($H4^{det}$); and 3) a higher level of organisation of NPD activities ($H8^{det}$). This makes sense, as the more people involved in a project, from within or outside the firm, the better the chance that somebody will 'bring along' or impose a tool to assist in some aspect of NPD. Firms in which the NPD processes are more elaborate are also more likely to include more tools than firms that have less formal NPD processes in place.

5.2.7 Obstacles to Tool Adoption

I asked survey participants to identify the barriers, from a list provided in Figure 23, which prevented their business units adopting more NPD tools in developing the products under consideration. The list items were compiled from a literature search of research among large firms (Feldman & Page, 1984; Hidalgo & Albors, 2008; Verhage, et al., 1981; Yeh, et al., 2008b), but no quantifiable data is available for comparison purposes. As expected, the associated cost of tool adoption is of concern to half of the firms in the survey. Smaller firms are generally more resource-stricken than larger firms, which may explain why they are reluctant to invest in tools perceived to require significant investment in time and money. Of concern is that over 50% of firms in the sample question the tool ROI and doubt the value of NPD tools. Unless such firms can be convinced of achieving worthwhile returns on their investments, the uptake of tools will remain at low levels. More than 40% of firms believe that adopting more tools in their NPD efforts is too difficult from a resource, culture and/or process perspective. Individual comments such as "sometimes these tools are just too 'heavyweight' for us" and "there are only two of us" underline the small-firm problem. More than half of the survey respondents unashamedly admitted that they were not aware that more tools were available. Greater promotion of tools among NPD firms could improve the situation.

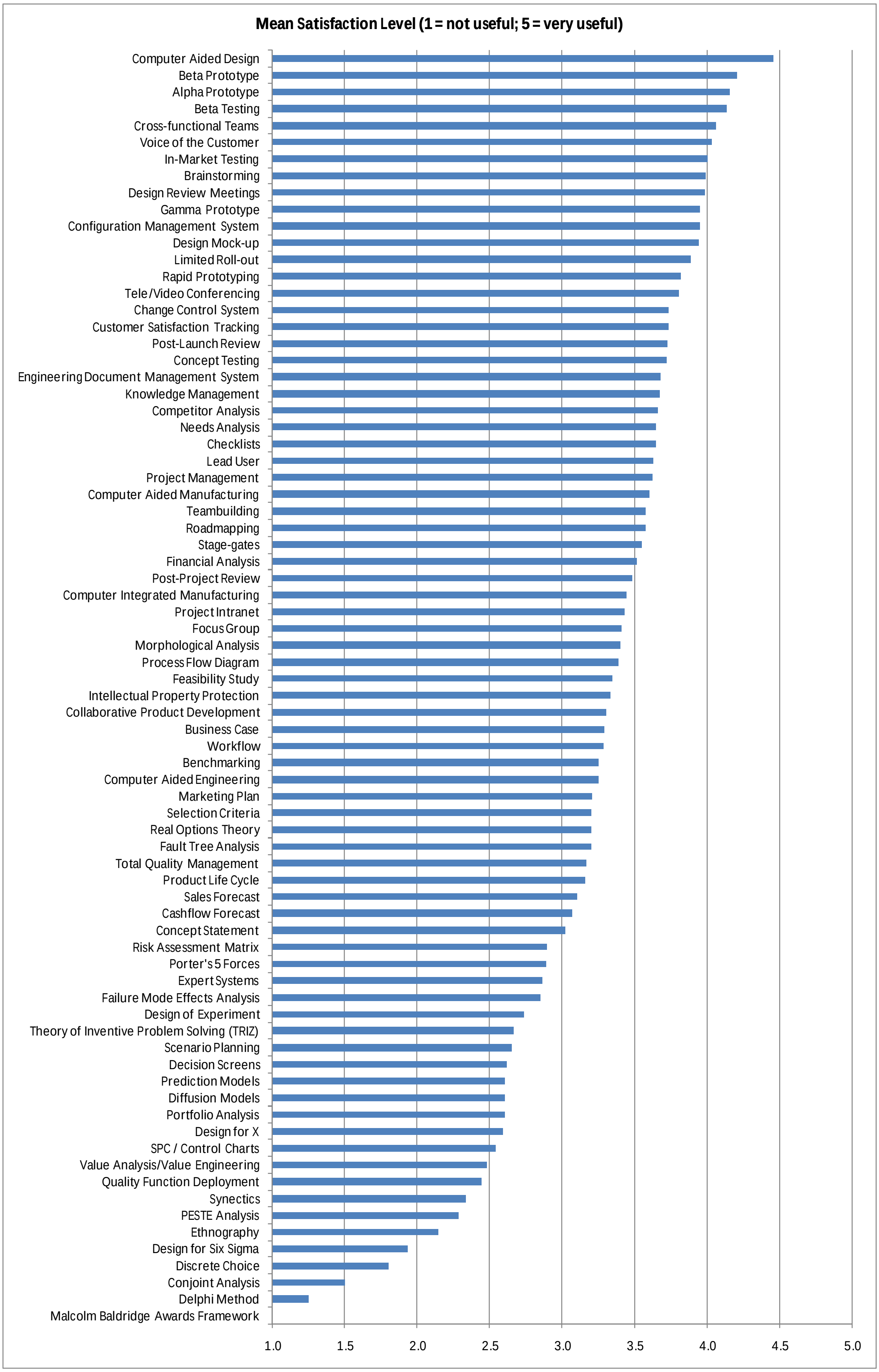
Figure 23. Obstacles to tool adoption



5.2.8 Tool Satisfaction / Usefulness

Figure 24 shows the spread in mean satisfaction levels (expressed in terms of usefulness) with the tools used by respondents for the specific projects under consideration. Looking at the upper echelon of tools in this list could be quite useful to firms intending to introduce new tools, as they come highly recommended. Note that these satisfaction values only reflect managers' perceptions with regard to tool application as it relates to the NPD projects that form part of this study - it does not reflect their satisfaction levels of these tools in general. Managers' satisfaction levels, or the tools' perceived usefulness, are therefore outcomes of a process (dependent variables) and therefore cannot be considered in the context of them being a determinant of tool adoption (being the independent variable). Of the 76 tools studied in this research (see Figure 24), only 30 (approximately 40%) achieve mean satisfaction levels greater than 60% (3.5 on a scale of 1 (not useful) to 5 (extremely useful)).

Figure 24. Mean satisfaction level of tools



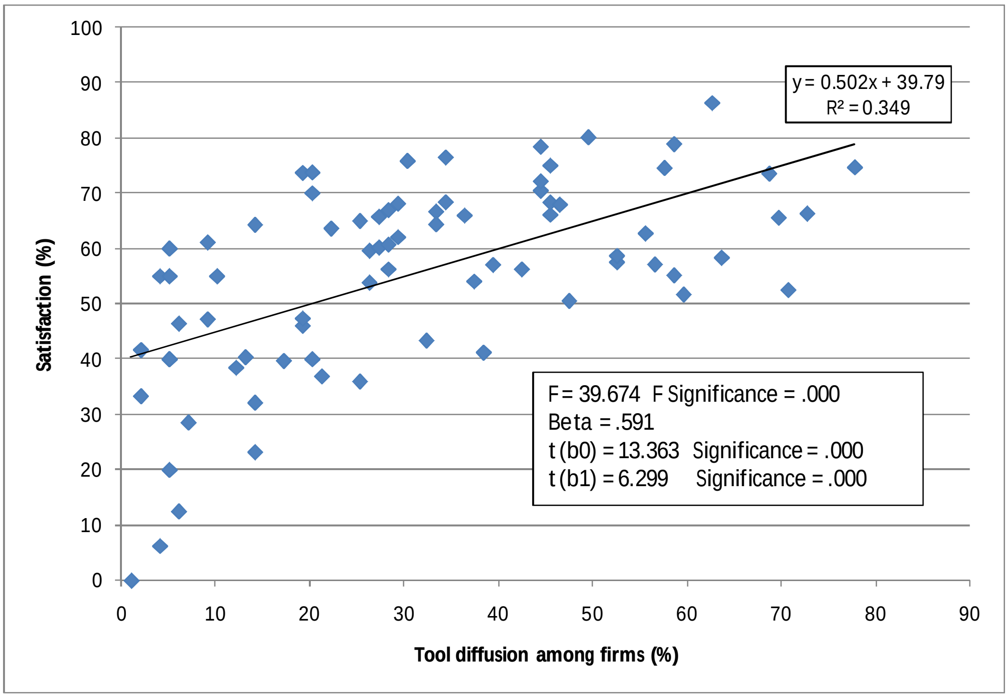
Relationship between tool diffusion among firms and perceived tool usefulness

> *H1^useful: The level of tool adoption is not associated with managers' perceptions of tool usefulness*

Figure 25 and a corresponding regression analysis indicate statistically significant higher satisfaction levels for tools with higher diffusion rates among firms than for lower ones. Some low-use tools with diffusion rates below 10% still manage to obtain relatively high satisfaction rates between 50 and 60%.

These tools are 'selection criteria', 'computer integrated manufacturing', 'fault tree analysis', 'morphological analysis', and 'real options theory'. Tools achieving lower than 30% satisfaction ratings are 'ethnography', 'design for six sigma', 'discrete choice', 'conjoint analysis', 'Delphi method', and 'Malcolm Bainbridge Awards Framework'.

Figure 25. Tool diffusion among firms versus tool satisfaction



Relationship between thoroughness of tool use and perceived usefulness

> *H2^useful: The thoroughness levels of tool application are not associated with managers' perceptions of tool usefulness*

A plot of the cumulative data for all 99 cases and 76 tools (see Figure 26) and linear trendline fitted to the data (R^2=.821) provide a first indication that a positive relationship does exist. This was confirmed by a linear regression analysis that rejected the null hypothesis at the 99%

confidence level (F = 299.173, F Significance = .000, Beta = .906). I therefore conclude that tool users are likely to be more satisfied with the tools they use the more thoroughly they apply these tools.

5.2.9 Relative NPD Performance Ratings in Product and Process

Performance enhancement in NPD involves both improving the outcome of the process (the product itself) and improving the process itself (e.g. faster time to market, reducing development costs, etc.) (Maylor, 2001). In this section, I make extensive use of a range of performance indicators that I identified from past research (Griffin, 1997a; Kleinschmidt, 1994; Nijssen & Frambach, 2000; Nijssen & Lieshout, 1995; Yeh, et al., 2008b). Section 4.4.2 (p. 73) details the rationale I used in selecting 12 specific performance measures for this study.

Figure 26. Thoroughness of tool use versus perceived usefulness

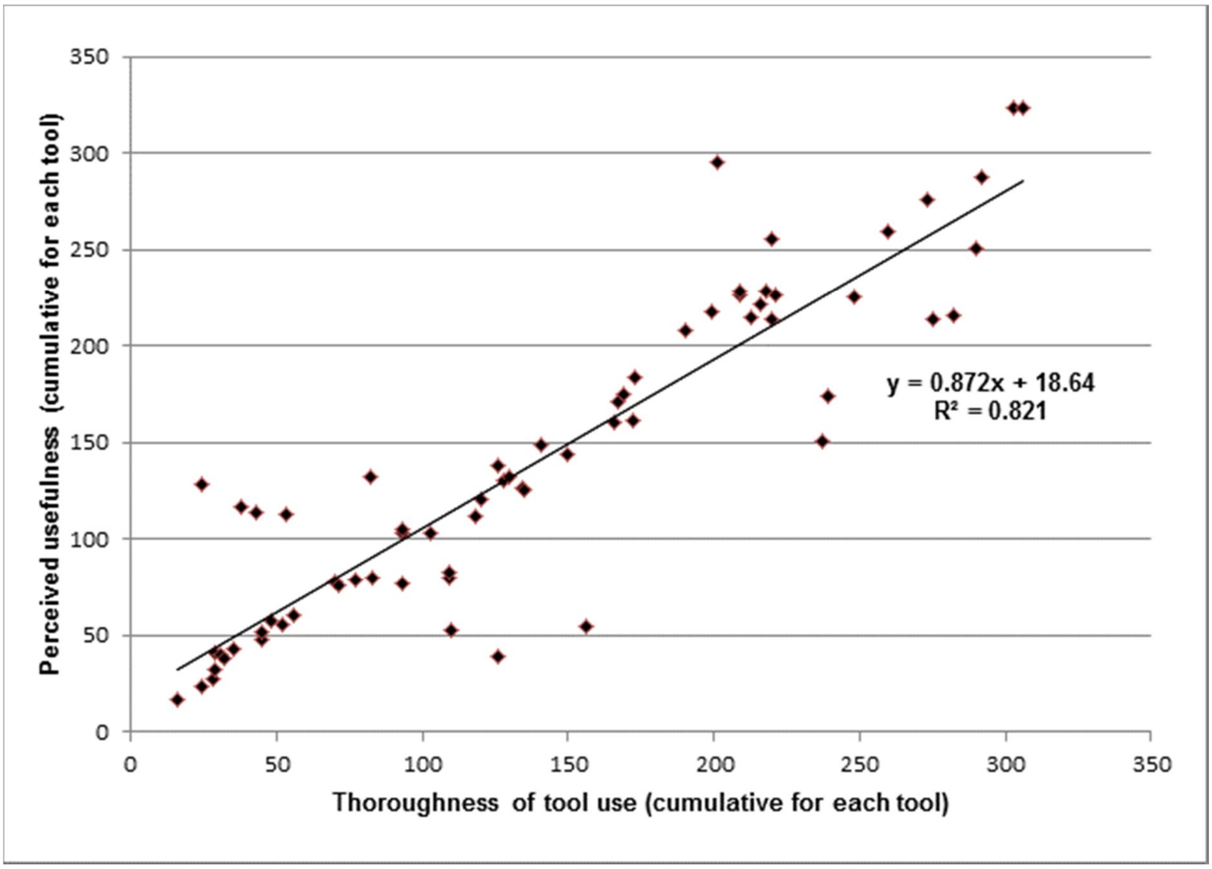


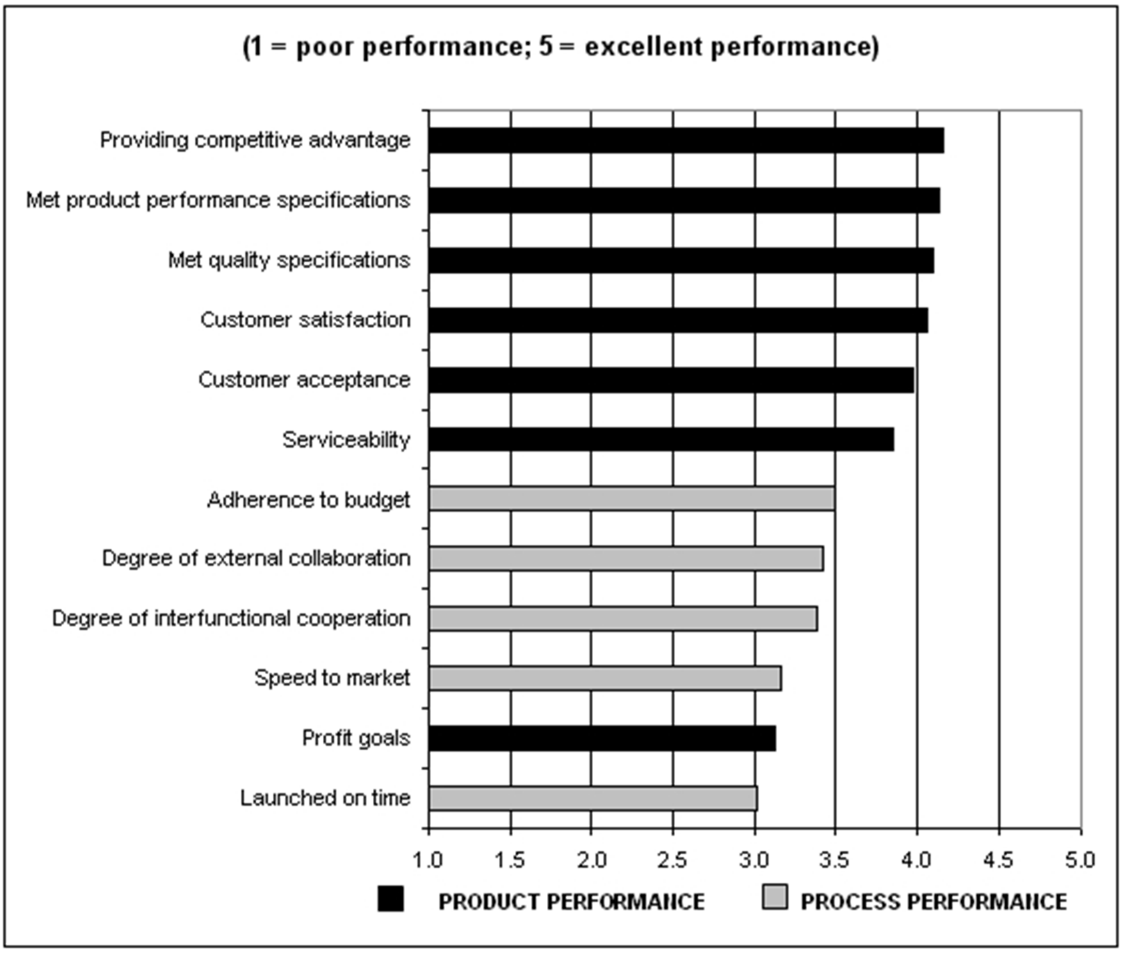
Figure 27 shows the 12 mean NPD performance ratings for the 99 projects that form part of this study. The performance ratings are perceptual, as they are based on participants' subjective ratings of their projects' performance for each of the 12 variables on a 5-point Likert scale where 1 = 'poor' and 5 = 'excellent'. The fact that I used 12 very specific measures to assess one very specific project that was completed in the not-too-distant past would arguably lessen the tendency among respondents to overstate performance. Measuring performance in the manner of this study is essentially a positivist approach where subjective measurements are interpreted by quantitative techniques - shown by Graetz, et al. (2006) to be a legitimate approach for measuring and evaluating (process) factors. (The section ‘scale merits and limitations’ (p. 77) provides a detailed discussion of the nature of subjective measures used in this study.)

On average, none of the ratings scores above 4.2 out of 5, which implies that the respondents in the sample firms do not believe they have achieved excellence in any particular aspect of NPD. The three worst performance areas are ‘speed to market’, ‘achieving profit goals’ and ‘launched on time’. Similar studies done in the USA (Cooper & Edgett, 2005), though generally using different measures, reported similar findings for these poor performing areas: 32% of the firms in the study rated their NPD speed and efficiency as very poor; 44% of projects failed to achieve profit targets; and only 51% of projects were launched on time. Comparative data for the remaining measures does not exist.

The top six performance measures (means greater than 3.5) all relate to the product (project outcome) itself: providing competitive advantage, meeting product performance specifications, meeting quality specifications, customer satisfaction, customer acceptance, and serviceability.

This is an indication that small firms generally succeed relatively well at creating technically great products that are accepted by customers and meet their needs. Still, as can be seen from Figure 27, there is further scope for improvement in this regard. However, participants to this study rate the remaining six performance measures, which all have a distinct process flavour (except for the product’s profit goals), as mediocre (means between 3 and 3.5). Thus, it appears that small firms’ relative success at developing great products comes in spite of their relative underperformance in the NPD process domain.

Figure 27. Mean NPD project performance ratings among small firms



5.2.10 Impact of NPD Process on Performance Measures

*H1^{perf}: The presence of a formalised NPD process is positively associated with NPD performance**

*H2^{perf}: The level of NPD process sophistication is positively associated with NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73))

As discussed in Section 5.2.1 (p. 106), and as is clear from Figure 28, small firms appear to take a casual approach to NPD. This finding supports that of past research that pointed to the informal way of conducting NPD in small firms (Section 2.4.1, p. 37). In testing for *H1^{perf}*, I combine the cases of the two lower bars in Figure 28 under the category of 'No NPD process or no formalised process', and in similar fashion I combine the two upper bars under the heading 'Formalised NPD process'. Contrary to expectation, the Chi-square (crosstabs) analysis yields no significant test results at the 95% confidence level, hence there is no support for $H1^{perf}$. However, a means plot of the 12 performance measures in Figure 29 shows consistently higher mean values when a formalised process is present.

Testing for process sophistication, I use the four categorical variables in Figure 28. As can be seen from the one-way ANOVA and Pearson's chi-square test (crosstabs) outputs in Table 19, three performance measures test significantly at the 95% confidence level, and for these measures, the tests support the hypothesised association $H2^{perf}$. They are 'speed to market', 'launched on time', and 'adherence to budget'. Another performance measure, 'degree of external collaboration', tests significantly at a 92.8% confidence level.

The remaining eight performance measures deliver insignificant test results at the 95% confidence level, hence the hypothesised association $H2^{perf}$ is not supported for these measures. A closer inspection of the four 'significant' results indicates that all four are process performance measures and that all are positively correlated with the level of NPD process sophistication (positive R-values).

Figure 28. NPD process sophistication among small firms

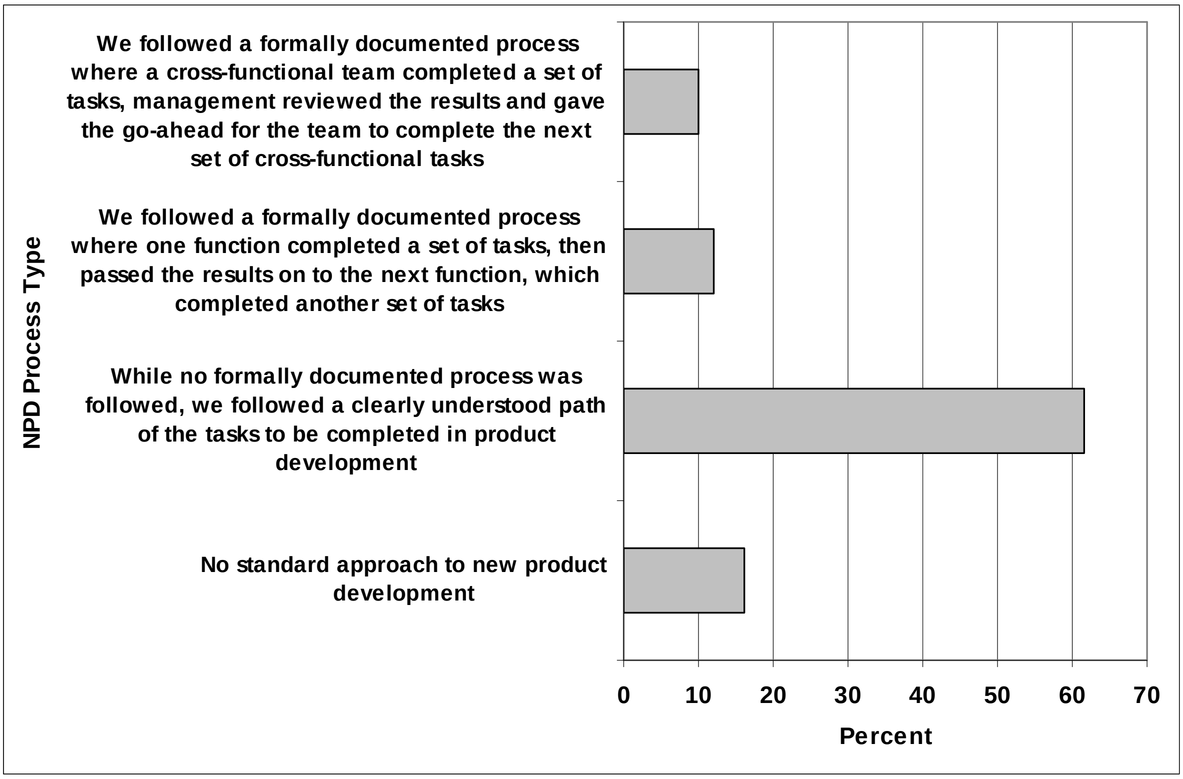
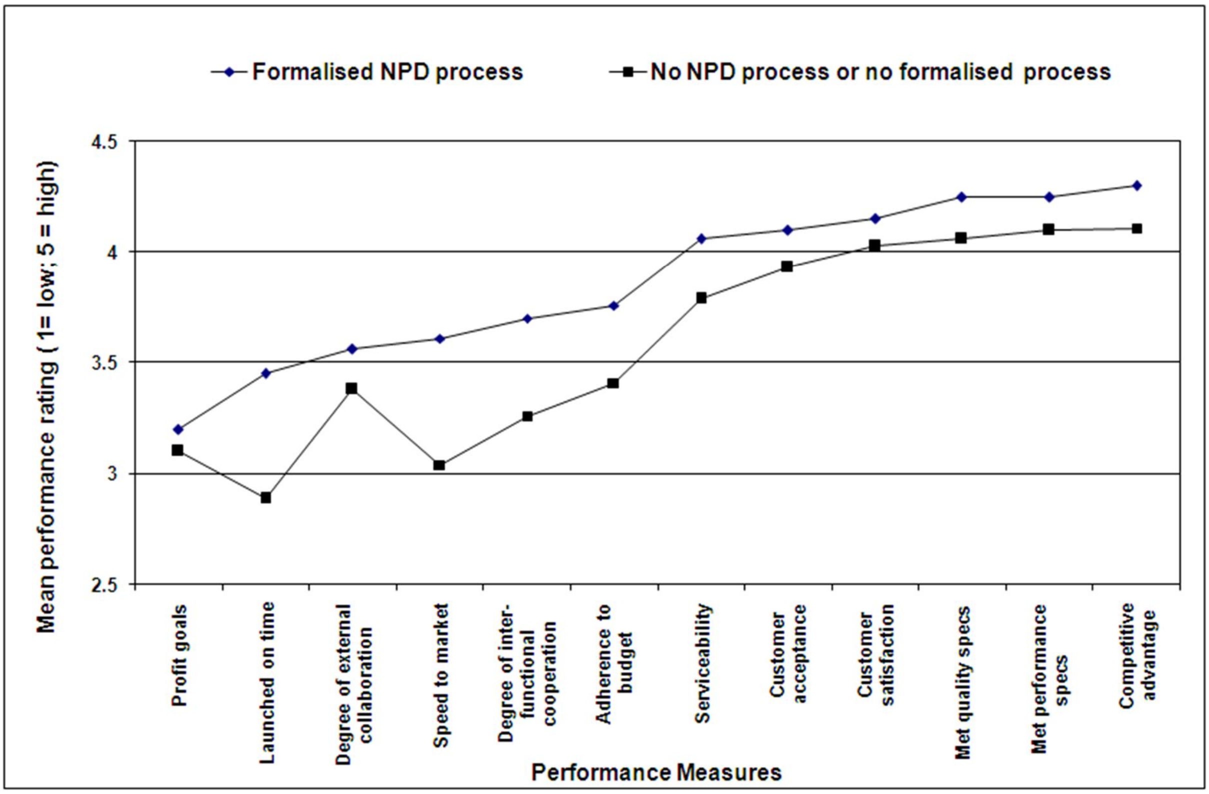


Figure 29. Impact of formalised NPD process on performance measures



Only one process performance measured in this study, the degree of inter-functional cooperation, tests insignificantly. The positive relationship with performance is not unexpected, as process sophistication should be associated with improved process performance. More specifically, my findings imply that the more sophisticated and structured firms' NPD processes are, the faster they will be able to transform new ideas into marketable products; the better they will be able to keep to plans and budgets; and the greater the collaboration will be with third party developers.

In the case of all seven of the product performance measures in the study, I find the association with process sophistication positive but not statistically significant. Although this seems unexpected, it aligns with findings from other authors. It seems that improved new product outcomes arise not from the presence of a process per se, but from how well the firm executes this process (Cooper & Kleinschmidt, 1987; Millson & Wilemon, 2006). A likely explanation for my findings is that firms' level of NPD process proficiency was sufficient to deliver significant positive correlations with process outcomes, but not sufficient to show significant positive correlations with product success. Millson and Wilemon (2006) defined NPD process proficiency as how well NPD activities, stages, and the NPD process as a whole are performed.

Table 19. Hypotheses testing: NPD process sophistication vs performance

NPD Performance Measure	N	Pearson's R	ANOVA		Chi-square (crosstabs)	
			F	Sig.	Value	Asymp. Sig. (2-sided)
Speed to market	86	.210	3.911	.051*	3.783	.052*
Launched on time	86	.259	6.040	.016*	5.702	.017*
Adherence to budget	89	.238	5.233	.025*	4.993	.025*
Inter-functional cooperation	73	.166	2.004	.161	1.976	.160
External collaboration	71	.215	3.330	.072†	3.223	.073†
Met product specifications	89	.076	0.508	.478	0.511	.475
Provide competitive advantage	92	.108	1.070	.304	1.069	.301
Met quality specifications	91	.054	0.262	.610	0.265	.607
Product serviceability	85	.141	1.681	.198	1.668	.197
Customer acceptance	91	.019	0.032	.859	0.032	.857
Customer satisfaction	88	.046	0.183	.670	0.185	.667
Met profit goals	80	.114	1.032	.313	1.032	.310

Note: As the degree of NPD process sophistication is a categorical variable, the most appropriate test is Pearson's chi-square test. However, as the comparative results show, the ANOVA test statistics are a good approximation when the NPD process sophistication measurement scale is taken as interval because of the large sample size.
*p<.05; †p<.075

Another possible explanation for the lack of statistically significant associations could be the nature of my dataset, which has only 12 cases of the top level of formally documented processes, and 10 cases for somewhat advanced documented processes, compared to the 77 cases that had no formally documented processes (refer to Figure 28). This may make it harder for the statistical tests to show significant results for the product measures because of their weaker associations than for the process measures (see Table 19).

5.2.11 Impact of Innovation Strategy on Performance Measures

*H3^{perf}: The presence of an innovation strategy is positively associated with NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

Only slightly over one third of respondents confirmed that formal innovation strategies of their organisations guided their development projects. Just as I found for process sophistication, small firms were left in the wake of their larger American (Adams, 2004), Swedish (Rundquist & Chibba, 2004) and Malaysian (Al Shalabi & Rundquist, 2009) counterparts, for which the corresponding figures were 80%, 73.3% and 76%, respectively.

The Chi-square (crosstabs) test results yielded only two tests that provide statistically significant support for the hypothesised relationship $H3^{perf}$: ‘launched on time’ (value = 4.311, sig. = .038) and ‘degree of inter-functional cooperation’ (value = 4.643, sig. = .031). Although the presence of an innovation strategy appears to have no statistically significant impact on the remaining ten performance measures, the means plot shown in Figure 30 shows consistently higher mean values when an innovation strategy is present. This finding partially supports earlier research by Terziovski (2010) who found a positive and significant relationship between innovation strategy and SME performance.

5.2.12 Relative NPD Performance Ratings by Project Strategy

In this section, I drill down into the results of Figure 27 to assess the 12 performance measures for each of the six types of project strategies that form part of this study. In Table 20, I define and calculate the project strategy overall performance index as the arithmetic mean of the strategy’s 12 performance measures. At the bottom end of the performance scale is the cost-reduction project strategy with an overall performance index of 3.08. I acknowledge that the small number of cases (N = 4) in this particular category may reduce the external validity of this finding. For this strategy Griffin and Page (1996) suggest the most useful measures are profit goals (my mean score 2.50), customer satisfaction (2.00) and meeting quality specifications (3.00) and performance specifications (3.00). Griffin and Page suggest that cost reduction ought not to be at the expense of these measures, but in my sample cases, the performance is strikingly low across all four measures. A possible explanation is that these products were already in trouble prior to the project and this motivated the cost reduction effort. If so, the cost-reduction strategies did little to improve the situation, and probably were not worth pursuing. This strategy did not seem to produce desired outcomes, with the single exception of the rating for competitive advantage (4.50 versus a 4.15 mean performance across all strategies).

Product repositioning strategies seem to fare slightly better than cost reductions as customers largely appear to accept the rejuvenated products (4.29), but the resulting profit outcomes are below average (2.67) relative to the mean performance outcome for profit goals (3.13).

A third appropriate success measure for repositioning strategies is competitive advantage provided (Griffin & Page, 1996), though it appears that, together with incremental improvements, this project strategy is the least successful of the six (3.67).

Figure 30. Impact of innovation strategy on performance measures

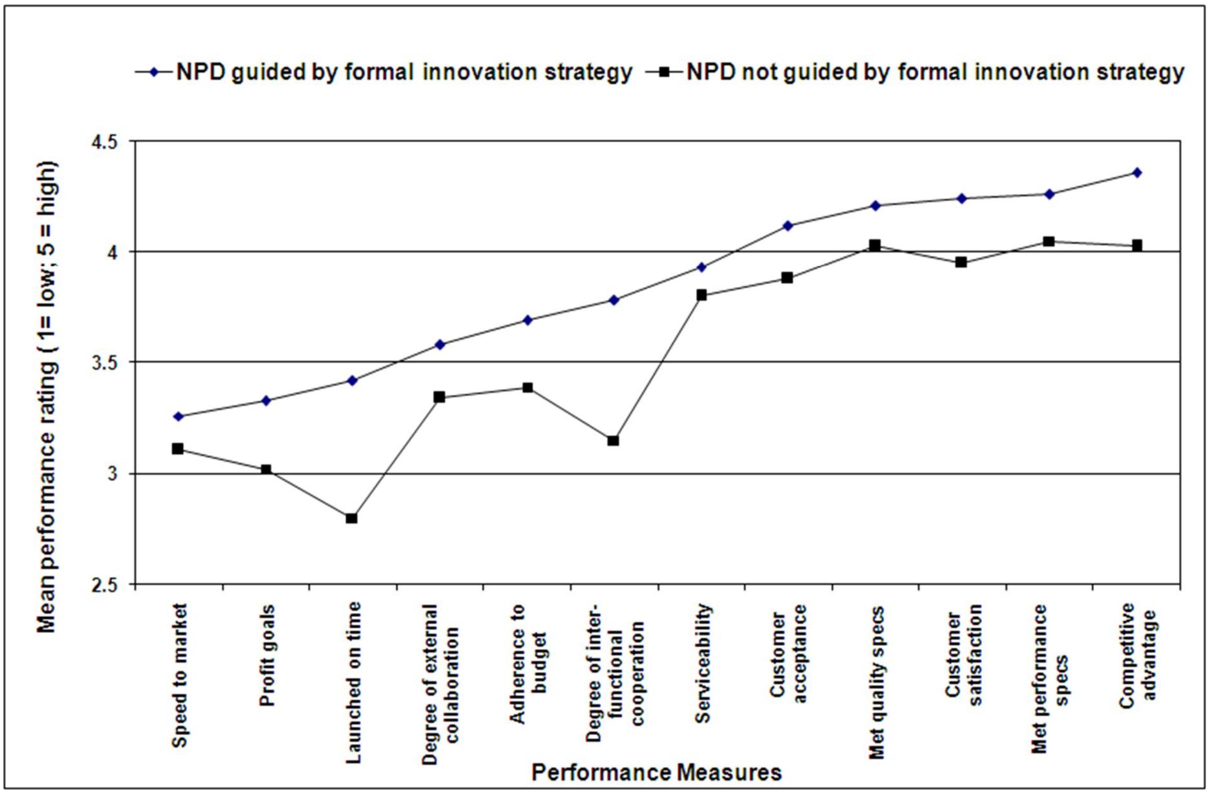


Table 20. Mean NPD performance ratings among small firms

Performance Measures (in order of ascending mean performance)	Performance means	Project Strategies: Cost reductions N=4	Repo-sitionings N=8	Incremental improvements N=23	Additions to existing lines N=26	New-to-the-firm projects N=11	New-to-the-world projects N=27
Launched on time	**3.02**	2.50	2.67	3.07	3.46	3.00	3.54
Profit goals	**3.13**	2.50 *	2.67 *	2.87 *	3.46 *	3.33 *	3.38 *
Speed to market	**3.16**	3.00	3.33	2.93	3.69	3.00	3.77
Degree of interfunctional cooperation	**3.38**	3.50	2.67	3.53	3.46	3.00	3.69
Degree of external colaboration	**3.42**	4.00	2.33	3.13	3.54	3.67	3.38
Adherence to budget	**3.49**	3.00	2.33	3.20	3.69	4.00	3.69
Serviceability	**3.85**	3.50	4.00	3.80	3.92	4.50	4.08
Customer acceptance	**3.97**	2.50	4.29 *	3.80	4.38 *	4.33	4.08 *
Customer satisfaction	**4.06**	2.00 *	4.00	3.87 *	4.31 *	4.33 *	4.31 *
Met quality specs	**4.10**	3.00 *	4.14	4.13	4.15	4.17	4.15
Met product performance specs	**4.13**	3.00 *	4.67	3.80 *	3.92	4.33	4.08
Provide competitive advantage	**4.15**	4.50	3.67 *	3.67 *	4.15 *	4.50 *	4.46 *
Overall Performance Index		**3.08**	**3.40**	**3.48**	**3.84**	**3.85**	**3.88**

* Most useful success measures as suggested by Griffin and Page (1996)

Incremental improvement projects create the next-generation performance modification for currently sold products (Griffin & Page, 1996). Disappointingly, this strategy fails to shine in all three of its most useful performance measures: profit goals (2.87), satisfying customers (3.87), and providing competitive advantage (3.67).

The three remaining project strategies all appear to achieve satisfactory outcomes with most of the individual performance ratings outscoring the performance means. Apart from meeting expected profit goals, all of the most useful success measures achieve ratings above 4.00. It seems that small firms are having more success with the three new-product strategies to the right in Table 20 than with the three improvement strategies to the left.

5.2.13 Impact of Individual Tools on Performance Measures

*H5xy^{perf}: The application of tool x in tool category y is not associated with NPD performance**

Where tool x represents one of several chosen tools in each of the 12 categories of tools (y = 1 to 12) defined in Sections 2.2.5 and 2.2.6

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

I analysed the impacts of the 76 individual, but categorised NPD tools on each of the 12 performance indicators using bivariate correlation analysis. Table 21 and Table 22 respectively list the correlation factors of those support and functional tools that I found to have had significant impact on at least one of the 12 NPD performance areas. Out of the 76 tools in this study, 45 (60%) had a significant positive impact on at least one of the 12 performance areas. Overall, the functional tools appear to have a greater impact on performance indicators than the support tools. The top-performing functional tools, in terms of the number of significant impacts on performance indicators (shown in brackets), are: 'In-market testing' (9); 'concept-testing' (8); 'PESTE analysis' (7); 'needs analysis' (7); 'value analysis/value engineering' (5); and 'project management' (5). Similarly, the top-performing support tools are: 'Customer satisfaction tracking' (5); 'brainstorming' (5); and 'design review meetings' (3). Comparative data for larger firms are scarce, though the work of Yeh, et al. (2008b) found evidence in support of the current findings for tools having an impact on NPD performance, as well as for four tools that tested insignificant in this study: 'modular design', 'DfX', 'CAM/CAE', and 'cross-functional teams'. These results provide guidance for firms wishing to improve their NPD performance with respect to specific indicators. For example, if a project team wished to improve its performance with respect to product quality (PM8 performance indicator), it should emphasise using 'alpha prototype', 'VA/VE', 'limited roll-out', 'control charts', 'knowledge management', 'benchmarking', and 'customer satisfaction tracking'.

Twenty-six tools (34% of the tools included in this study) show no significant correlation (at the 95% confidence level) with any of the performance areas. Among those are low-adoption tools with diffusion-among-firm rates less than 15%, including ‘DfX’, ‘diffusion models’, ‘CIM’, ‘Delphi method’, ‘synectics’, ‘TRIZ’, ‘computer prediction models’, ‘risk assessment matrix’, ‘expert systems’, ‘Malcolm Baldridge Awards Framework’, ‘real options theory’, ‘decision screens’, and ‘selection criteria’. Factors potentially contributing to the lack of performance correlation for this group of tools may be insufficient qualifying samples in the survey to calculate meaningful trends, or more likely, the fact that the firms did not use the tools thoroughly. I investigate the effect of thoroughness of use later in this chapter.

The results furthermore indicate that five tools correlate significantly with adverse effects on one or more NPD performance measures. They are ‘project intranet’, ‘configuration management system’, ‘checklists’, ‘computer aided engineering’, and ‘design for six sigma’. This finding does not implicate these tools as ‘ones that should be avoided’, as their use has resulted in several positive, but not significant, associations in other areas of NPD performance. I discuss this in more detail in the final chapter.

For convenience, I conducted a factor analysis of the 12 performance measures in an effort to reduce the number of performance outcomes. This was indeed possible, reducing the number of 12 performance measures to only three factors. Six variables load significantly on factor F1. By closer inspection, meeting or exceeding a product’s performance and quality specifications together with improved serviceability, could lead to achieving competitive advantage, eventually resulting in greater customer acceptance and customer satisfaction. Therefore, it is not surprising to see these ‘outcomes of a NPD project’ or ‘Product’ variables grouped together. Factor F2 has high loadings for speed to market, launched on time, adherence to budget, degree of inter-functional cooperation, and degree of external collaboration. These are all elements that relate to the efficiency of the NPD process. The three most highly loaded elements in factor F3 are customer acceptance and satisfaction, and profit goals. These are all measures of market success. The Principal Component Analysis of the outcome variables are shown in Table 23 (only factors with an eigenvalue > 1 were retained).

Table 21. Significant support tool performance correlations

	Support Tools	Performance Measures												
		PM1	PM2	PM3	PM4	PM5	PM6	PM7	PM8	PM9	PM10	PM11	PM12	Total
Creativity & Problem Sol.	Brainstorming		.291*		.477**	.429**				.205*			.213*	5
	Delphi Method													0
	Focus Group	.369*			.472*									2
	Morphological Analysis													0
	Product Life Cycle	.367*									.377*	.398*		3
	Roadmapping					.526*								1
	Synectics													0
	TRIZ													0
KM	Engineering Document Mgmnt System													0
	Knowledge Management						.472**		.303*					2
	Project Intranet							-.371*						1
	Change Control System	.315*	.290*											2
	Configuration Management System	.398*	.397*			.589**							-.452*	4
Risk	Failure Mode Effects Analysis (FMEA)				.499*									1
	Fault Tree Analysis			.866*										1
	Market/Computer Prediction Models													0
	Risk Assessment Matrix													0
Team	Cross-functional Team													0
	Tele/Video-conferencing				.516*									1
	Design Review Meetings					.423**				.243*			.264*	3
	Workflow													0
	Teambuilding					.380*								1
Learning & Review	Expert Systems													0
	Benchmarking								.424*					1
	Customer Satisfaction Tracking						.410**		.339*		.517**	.476**	.334*	5
	Malcolm Baldridge Awards Framework													0
	Post-Launch Review						.382*				.362*	.362*		3
	Post-Project Review				.430*						.386*	.386*		3
Decision	Stage-gates													0
	Real Options Theory													0
	Checklists	-.321*												1
	Decision Screens													0
	Selection/Evaluation Criteria & Screening													0

PM1: Speed to Market **PM2**: Launched on time **PM3**: Within budget **PM4**: Interfunctional cooperation **PM5**: External collaboration **PM6**: Performance specs

PM7: Competitive advantage **PM8:** Quality specifications **PM9:** Serviceability **PM10:** Customer acceptance **PM11:** Customer satisfaction **PM12:** Profit goals

*: p-value<.05; **: p-value<.01 Empty cells: Insignificant correlations

The rotated factor matrix (Varimax with Kaiser Normalisation) is shown in Table 24. Highlighted elements indicate a high loading (> 0.55 or < -0.55).

Having reduced the number of performance outcome variables from 12 to three, I tested for correlations among the 76 tools and the three performance factors (F1 = product performance; F2 = process efficiency; F3 = market performance). For ease of use, I only show the significant correlations in Table 25, of which there are 26. As before, the majority of the 'performance-impact' tools come from the functional tool category. Twelve tools significantly affect product performance (F1), 11 tools significantly affect process efficiency (F2), while only three tools seem to have a significant impact on market performance (F3). Overall, only 23 out of 76 tools significantly influence the three broad areas of NPD performance. This is fewer than when the 12 performance areas were considered separately, which is to be expected as considerable detail is lost when using the three-dimensional performance schema.

Table 22. Significant functional tool performance correlations

Functional Tools		Performance Measures												
		PM1	PM2	PM3	PM4	PM5	PM6	PM7	PM8	PM9	PM10	PM11	PM12	Total
Engineering and Design	Collaborative Product Development				.362*	.331*							.310*	3
	Computer Aided Design (CAD)					.321*								1
	Computer Aided Engineering (CAE)												-.380*	1
	Design of Experiments (DOE)				.405*			.388*						2
	Design for X (DfX)													0
	Quality Function Deployment (QFD)													0
	Design Mock-up					.297*								1
	Alpha Prototype						.333**		.251*	.309*				3
	Beta Prototype													0
	Gamma Prototype													0
	Design for Six Sigma												-.631*	1
	Value Analysis/Value Engineering (VA/VE)							.390*	.374*	.397*	.638**	.553**		5
	Rapid Prototyping			.339*										1
Strategy	Portfolio Analysis			.554**	.418*									2
	PESTE Analysis	.584*	.556*	.528*	.552*	.805**		.562*				.546*		7
	Porters Five Forces			.747*	.788**	.827*		.755**						4
	Intellectual Property Protection				.259*		.283*	.451*						3
	Competitor Analysis													0
	Scenario Planning	.315*	.489**			.329*	.308*							4
Market & Market Research	Conjoint Analysis				.964**	.813*								2
	Discrete Choice													0
	Ethnography	.837**								.757*				2
	Voice-of-the-Customer (VOC)					.420*								1
	Diffusion Models													0
	Lead User	.456**				.650**					.374*	.444*		4
	Needs Analysis		.341*		.355*	.374*		.275*			.362**	.325*	.282*	7
	Concept Testing	.312*			.344*	.331*	.292*	.434**			.254*	.277*	.276*	8
	Beta-testing				.394**	.271*								2
	In-market Testing	.408**	.426**	.349*	.459**			.268*		.481**	.396**	.419**	.289*	9
	Limited Roll-out (Test Marketing)				.431**	.324*			.331*		.278*			4
Fin	Financial Analysis (ROI,Breakeven)													0
	Sales Forecast													0
	Cashflow Forecast			.251*										1
Gen Management	Concept Statement				.362*								.325*	2
	Project Management	.207*	.252*			.254*				.226*			.226*	5
	Feasibility Study					.402**								1
	Business Case				.338*	.469**							.291*	3
	Marketing Plan										.244*	.256*		2
	Total Quality Management (TQM)											.314*		1
Manufacture	Statistical Process Control / Control Charts								.590*					1
	Process Flow Diagram				.428*	.388*								2
	Computer Integrated Manufacturing (CIM)													0
	Computer Aided Manufacturing (CAM)													0

PM1: Speed to Market **PM2**: Launched on time **PM3:** Within budget **PM4:** Interfunctional cooperation **PM5:** External collaboration **PM6**: Performance specs
PM7: Competitive advantage **PM8:** Quality specifications **PM9:** Serviceability **PM10**: Customer acceptance **PM11**: Customer satisfaction **PM12**: Profit goals

*: p-value<.05; **: p-value<.01 Empty cells: Insignificant correlations

Table 23. Principal component factors

Factor	Eigenvalues	% of variation	Cumulative % of variation
1	5.697	43.821	43.281
2	2.129	16.375	60.195
3	1.208	9.290	69.486

Table 24. Rotated component matrix

Performance Measures (outcome variables)		Factors		
		F1	F2	F3
PM1	Speed to market	.224	**.846**	.058
PM2	Launched on time	.083	**.908**	.134
PM3	Adherence to budget	.036	**.659**	.375
PM4	Degree of inter-functional cooperation	.138	**.585**	.067
PM5	Degree of external collaboration	.124	**.601**	.397
PM6	Met product performance specifications	**.732**	.285	.081
PM7	Providing competitive advantage	**.804**	.179	.149
PM8	Met quality specifications	**.813**	.153	.103
PM9	Serviceability	**.785**	.055	.158
PM10	Customer acceptance	**.581**	.039	**.637**
PM11	Customer satisfaction	**.707**	-.013	**.571**
PM12	Profit goals	.213	.357	**.809**

Rotation converged in 6 iterations.

5.2.14 Intra-group Tool Impact on NPD Performance

Maylor (2001) suggested that investigating the impact of tools as single factors is inappropriate as it might distort the patterns of usage when multiple tools are applied to projects. He argued that firms rarely use tools in isolation and that in practice benefits are often simultaneously claimed by different initiatives - that overall patterns in tool use, rather than specific tools, lead to improvements.

It is evident from the table data in Appendix 8 that significant interaction effects among individual tools exist. For purpose of convenience, I show only the intra-group correlations of tool adoption among a random selection of 20 tools (out of 76). The considerable number of intra-group correlations that exist at the p = .05 and p = .01 significance levels is clearly visible. It is therefore reasonable to argue that practitioners do not use tools in isolation.

In view of this, I next attempt to group firms according to their observed patterns of tool usage. By systematically carrying out a series of two-step cluster analyses, I derived a classification scheme of firms according to tool adoption (tool diffusion within projects). As can be seen from Table 26, this classification scheme has three clearly defined homogeneous clusters in terms of mean tool diffusion within firms.

Table 25: Significant correlations between individual tools and performance factors

	Functional Tools	Performance Factors F1	F2	F3
Engineering and Design	Collaborative Product Development	.311*		.420**
	Computer Aided Design (CAD)			
	Computer Aided Engineering (CAE)			
	Design of Experiments (DOE)	.450*		
	Design for X (DfX)			
	Quality Function Deployment (QFD)			
	Design Mock-up	.456**		
	Alpha Prototype	.452**		
	Beta Prototype	.410*		
	Gamma Prototype			
	Design for Six Sigma			
	Value Analysis/Value Engineering (VA/VE)	.610*		
	Rapid Prototyping			
Strategy	Portfolio Analysis		.568*	
	PESTE Analysis		.713*	
	Porters Five Forces			
	Intellectual Property Protection			
	Competitor Analysis			
	Scenario Planning		.537**	
Market & Market Research	Conjoint Analysis			
	Discrete Choice			
	Ethnography	.971*	.835*	
	Voice-of-the-Customer (VOC)			
	Diffusion Models			
	Lead User		.441*	
	Needs Analysis			
	Concept Testing	.348*		.371*
	Beta-testing			
	In-market Testing	.473*		
	Limited Roll-out (Test Marketing)			
Fin	Financial Analysis (ROI,...)			
	Sales Forecast			
	Cashflow Forecast			
Gen Management	Concept Statement			.339*
	Project Management			
	Feasibility Study		.348*	
	Business Case		.317*	
	Marketing Plan			
	Total Quality Management (TQM)			
Manufacturing	Statistical Process Control / Control Charts			
	Process Flow Diagram		.402*	
	Computer Integrated Manufacturing (CIM)			
	Computer Aided Manufacturing (CAM)			

	Support Tools	Performance Factors F1	F2	F3
Creativity & Problem Sol.	Brainstorming		.296*	
	Delphi Method			
	Focus Group			
	Morphological Analysis			
	Product Life Cycle			
	Roadmapping			
	Synectics			
	TRIZ			
KM	Engineering Document Management System	.456*		
	Knowledge Management			
	Project Intranet			
	Change Control System			
	Configuration Management System		.469*	
Risk	Failure Mode Effects Analysis (FMEA)	.525*		
	Fault Tree Analysis			
	Market/Computer Prediction Models			
	Risk Assessment Matrix		.509*	
Team	Cross-functional Team			
	Tele/Video-conferencing			
	Design Review Meetings			
	Workflow			
	Teambuilding			
Learning & Review	Expert Systems			
	Benchmarking			
	Customer Satisfaction Tracking	.338*		
	Malcolm Baldridge Awards Framework			
	Post-Launch Review			
	Post-Project Review			
Decision	Stage-gates			
	Real Options Theory			
	Checklists			
	Decision Screens			
	Selection/Evaluation Criteria & Screening			

F1: Product performance
F2: Process efficiency
F3: Market performance

*: $p < .05$
**: $p < .01$
Empty cells: Insignificant correlations

Table 26. Cluster mean tool diffusion values

Cluster	Mean tool diffusion within firms (out of a possible 76 tools)	Std. Deviation	Cluster size (%)
Cluster 1	33.73 (high tool users)	8.068	44.4
Cluster 2	24.61 (moderate tool users)	9.983	18.2
Cluster 3	11.49 (low tool users)	5.905	37.4
Total	23.76 (31.3%)	12.660	100

Cluster 1 consists of firms with the highest tool adoption (high tool users), with a mean of 33.73 (out of a maximum of 76), cluster two are moderate tool users with a mean of 24.61 and cluster three are low tool users with a mean of 11.49. In terms of cluster size, these findings are very similar to those of Maylor (2001) who also derived a three-cluster classification scheme for larger firms (Table 27). This is a clear indication of external validity, in particular convergent or concurrent validity “when the instrument is highly correlated with responses on another instrument known to be measuring the same construct” (Page & Meyer, 2000, p. 86).

Table 27. Cluster comparison with Maylor’s research

Cluster	**Current research**		**Maylor** (2001)	
	Mean tool diffusion within firms (%)	**Cluster size (%)**	**Mean tool diffusion within firms (%)**	**Cluster size (%)**
Cluster 1	44.4	44.4	68.6	48
Cluster 2	32.4	18.2	51.0	22
Cluster 3	15.2	37.4	37.0	30

The similarity in cluster size is quite remarkable, given the difference in firm sizes for the two studies. In Maylor’s study, 57% of firms in the sample employ less than 500 people (a study of relatively large firms), while in the current study 91% of firms employ less than 100 people (a study of relatively small firms). It appears that approximately 45-50% of firms, irrespective of size, are relatively high users of tools. Around 20% of firms can be considered average users of tools, while the remainder, roughly a third of all NPD firms, are low tool users. Despite the similarity in cluster size, the mean diffusion rates in each cluster for small firms are roughly 20 to 25 percentage points lower than corresponding values for larger firms. These gaps may even be bigger when considering the almost 10-year time difference between the two studies.

I tested the stability (internal validity) of the cluster solution by randomly dividing the dataset into two subsets and performing an analysis on each subset separately, a method proposed by Everitt (1993). Solutions similar to those of the complete dataset were obtained from both sets, a first indication of internal validity. A comparison of the cluster cases of the two subsets with the cluster cases of the total sample revealed that only one case out of 99 was moved from one cluster to another, which further supports stability of the cluster solution. As a further test of stability I carried out a difference of means test on the clusters of the complete dataset and on the corresponding clusters from each half. In all three instances the clusters were shown by both a one-way ANOVA ($F = 83.152$, $p = 0.000$) and a Duncan’s range test (alpha = 0.05; cluster 3 < cluster 2 < cluster 1) to have significantly different means (the results of only the complete dataset are shown in brackets).

Testing if individual tools uniquely belong to one of the three identified clusters

> *H4^{adopt}: The use of an individual tool is independent of the cluster* membership*

Using Crosstabs (Pearson's Chi-Square and Cramer's V for symmetry), I found that for none of the 76 tools the null hypothesis was rejected at the 95% confidence level. Therefore, it can be said that for relatively small firms, individual tools appear not to be exclusively used by high, moderate, or low tool users. This finding is contradictory to Maylor's (2001), who found that 66% of the 21 tools in his study belonged exclusively to one of the three identified clusters. A possible explanation for these contradictory findings is that Maylor's study included only 46 firms whereas my sample was 99, thus increasing the likelihood that firms in a particular cluster would adopt a particular tool.

I furthermore investigated whether high, moderate and low tool users (as represented by the three clusters) use tools across the 12 perspectives, or only in a few. From Figure 31, which shows the normalised values of collective tool adoption across cluster and tool category, a clear pattern is evident, one where none of the firm clusters misses whole areas of NPD activity, or more specifically, any of the 12 tool categories. Rather, it appears cluster firms engage tools in all 12 categories, but proportionally so in relation to cluster membership.

Relationship between tool adoption and NPD performance

> *H6^{perf}: The level of tool adoption within projects is not associated with NPD performance**

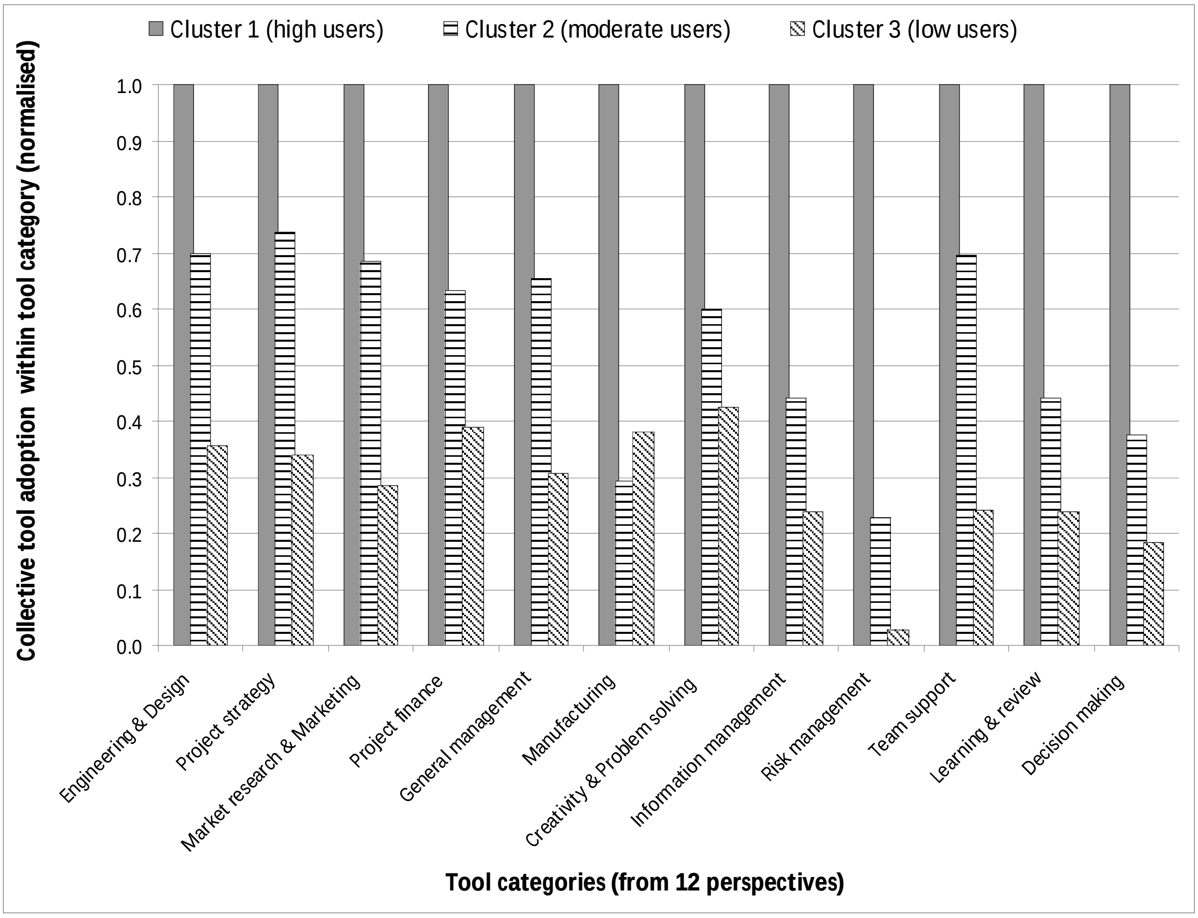
(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

To test the relationship between tool diffusion within firms and NPD performance, I express the proposed relationship in *H6^{perf}* in a form that incorporates cluster membership:

Performance improvement achieved = f(tool usage cluster membership) ....(A)

A one-way ANOVA compared the means of the three clusters (the independent variables on an ordinal scale) for each of the three performance factors (dependent variables on an ordinal scale). Contrary to expectation, at the 95% significance level I could not prove that any of the three clusters of tool usage have a significant positive impact on performance improvement of any type. In his study of 46 larger firms, Maylor (2001) found some evidence to suggest that higher levels of tool usage result in improved performance in some areas. As a double check, I ran the same analysis on the original 12 performance measures, but once again found no significant relationships. Because I felt that this failure to find a performance impact might be caused by some tool usage being superficial, I performed a second cluster analysis in which I defined tool diffusion more narrowly to include only tool thoroughness levels from three to five.

Figure 31. Cluster tool adoption within the 12 NPD perspectives



Once again, I derived three clusters, but there was still no significant difference in the means of the factors between the three clusters. From these results, I had to deduce that, for firms in this study, there appears to be no significant relationship between the number of tools that firms deploy and the performance outcomes obtained. Once again, I ascribe my contradiction with Maylor's finding to his relative small sample size.

My next objective was to identify any intra-group patterns among categories of tool application that could be significantly related to improved NPD performance. For this purpose, I used the tool categorisation scheme developed in Section 2.2.6 (p. 22), which categorises NPD tools in 12 distinct categories according to its functional and support perspectives in terms of the NPD process. I express this relationship as:

Performance improvement achieved = f(tool category utilisation) ....(B)

To test this relationship I defined 12 'tool category diffusion within firm' variables (TCP1 to

TCP12) for each of the 12 categories and calculated the corresponding values for each of the 99 cases in the research sample. (The TCP-values are simply the averages of the total number of tools deployed during a particular project belonging to a particular perspective.) As the survey included different numbers of tools associated with each category, these variables hold no meaning when compared among the group of 12 TCP-variables within the same case (intra-case). They are quite useful, however, for inter-case comparison with other variables, such as performance variables. In more specific terms equation B can be re-written as:

Performance improvement achieved = f(TCP1, TCP2, ..., TCP12) ....(C)

A one-way ANOVA analysis of equation C yielded significant results for only five of the 12 tool categories in combination with three of the performance factors (see Table 28). Factor 1 (product performance) is positively affected by tool usage in the marketing/market research and manufacturing categories. The former category includes tools such as ‘lead user’, ‘needs analysis’, ‘concept testing’, ‘in-market testing’ and ‘limited roll-out’, while the latter category includes tools such as ‘CAM’, ‘CIM’, ‘SPC/Control charts’ and ‘Process flow diagrams’. A strong customer focus during NPD is expected to pay dividends in terms of product performance, so the TCP3 relationship comes as no surprise. The usage patterns of manufacturing tools (TCP6) further enhance product performance in terms of minimizing product defects because of automated manufacturing and good quality control processes in place. Surprisingly, tool usage patterns in the TCP1 category (design and engineering) do not significantly enhance product performance. Instead, I found that the application of a combination of engineering tools from the TCP1 tool category such as ‘CAD’, ‘CAE’, and ‘prototyping’ result in greater market success in terms of customer acceptance, customer satisfaction and achieving sales and profit goals. In addition, tools in the decision-making category TCP12 also appear to enhance market performance, as logically practices that include the use of ‘stage-gates’, ‘checklists’, and ‘selection criteria’ should ensure that only the best products eventually end up in the marketplace.

Factor 2, termed process efficiency, seems to be only positively influenced by Market Research & Marketing tools. A possible explanation for this stems from Maylor’s research. He postulated that project costs (one of the major determinants of process performance) are not improved by a high use of tools as they come at a price (both time and money). In fact, I argue that increased tool usage may not only contribute towards increased project costs, but may also negatively impact the ‘speed to market’ and ‘launched on time’ elements.

Table 28. Results of ANOVA of three outcome factors for tool categorisation

Tool category	Description	Factor	F-value	Significance
TCP1	Engineering, R&D	F3 (Market performance)	2.693	.014
TCP2	Strategy	-----	-----	-----
TCP3	Market Research & Marketing	F1 (Product performance) F2 (Process efficiency)	2.324 2.171	.038 .052
TCP4	Project Finance	-----	-----	-----
TCP5	General Management	-----	-----	-----
TCP6	Manufacturing	F1 (Product performance)	5.096	.007
TCP7	Creativity/Problem solving	-----	-----	-----
TCP8	Information Management	-----	-----	-----
TCP9	Risk Management	-----	-----	-----
TCP10	Team Support	-----	-----	-----
TCP11	Learning & Review	-----	-----	-----
TCP12	Decision-Making	F3 (Market performance)	4.198	.011

The reason for this is that the purpose of most NPD tools is mainly to improve effectiveness in some regard, not necessarily efficiency. (One obvious exception would be concurrent engineering of which the main aim is increased efficiency.) While increased tool usage may on the one hand have negative impact on process performance, on the other hand any imposed deficiencies may be more than offset by the gains in project effectiveness as a result of increased tool usage. It is an established fact that increased investment in the activities of the front-end development stages pays off handsomely during later stages of the product life cycle in terms of products achieving greater market acceptance and satisfaction and experiencing a reduction in quality and other problems.

A final observation from Table 28 is the apparent failure of eight categories of tools to have any significant ‘tool-category’ impact on NPD performance. This result only implies that those specific patterns in tool usage associated with the various categories used in this research do not visibly contribute towards performance improvement. It may indeed be the case for other tool categorisation schemas not identified in this research. As shown earlier, the application of individual tools within these categories may indeed have a positive impact on NPD performance.

5.2.15 Thoroughness of Tool Use and NPD Performance

*H4^{perf}: Higher levels of thoroughness in tool usage are not associated with improved NPD performance**

(* NPD performance as it relates to 12 performance measures – see Section 4.4.2, p. 73)

The questionnaire captured respondents' perceptions of thoroughness levels on a five-point Likert scale, with one being 'not thorough' and five being 'very thorough'. Since I previously determined that the tools in the questionnaire all impact on NPD performance to hugely different degrees (some appear to have no impact at all), I tested the null hypothesis for only those tools (23 in total) that were implicated as significant performance enhancing tools for one or more of the three performance factors (F1, F2 and F3). The results of the one-way ANOVA (1-tailed tests) are shown in Table 29 (for convenience I list only findings within a 90% confidence level ($p < .1$)). Of the 23 tools under review, 10 delivered significant differences at better than 95% confidence levels (p-values $< .05$) in the performance means at different levels of thoroughness. For these tool cases, I reject the null hypothesis. Although I accept the null hypothesis for the remaining 13 tools, a closer inspection of the actual mean plots (see Figure 32) reveals that for all 23 tools a noticeable trend is apparent, one where NPD performance in a particular area improves with more thorough tool usage. Figure 32 graphically depicts the trends for the first six (engineering and design) tools of Table 29.

These trends were even more prevalent when I repeated the same exercise in plotting individual tool usage against its corresponding performance enhancing areas. For example, Figure 33 shows how more thorough usage of the 'In-market testing' tool translates into improved NPD performance in its nine performance-impact areas (as previously shown in Table 22).

Table 29. A comparison of mean performance for varying levels of tool usage

#	Tool	Factor 1		Factor 2		Factor 3	
		F-value	Sig.	F-value	Sig.	F-value	Sig.
1	Collaborative Product Development	3.072	.091			6.134	.020*
2	Design of Experiments	3.667	.080				
3	Design mock-up	7.913	.009**				
4	Alpha prototype	7.001	.014*				
5	Beta prototype	5.898	.023*				
6	Value Analysis/Value Engineering	4.981	.061				
7	Portfolio analysis			4.394	.066		
8	PESTE analysis			7.877	.038*		
9	Scenario planning			6.753	.021*		
10	Ethnography			4.824	.003**		
11	Lead user			4.225	.058		
12	Concept testing	3.355	.080			4.997	.035*
13	In-market testing	8.403	.009**				
14	Concept statement					3.338	.080
15	Feasibility study			3.172	.089		
16	Business case			3.212	.084		
17	Process flow						
18	Brainstorming			3.470	.071		
19	EDMS	5.897	.029*				
20	CMS			3.648	.083		
21	FMEA	3.755	.094				
22	Risk analysis matrix						
23	Customer satisfaction tracking	3.108	.091				

*: p-value < .05 **: p-value < .01

Figure 32. Product performance versus thoroughness of use

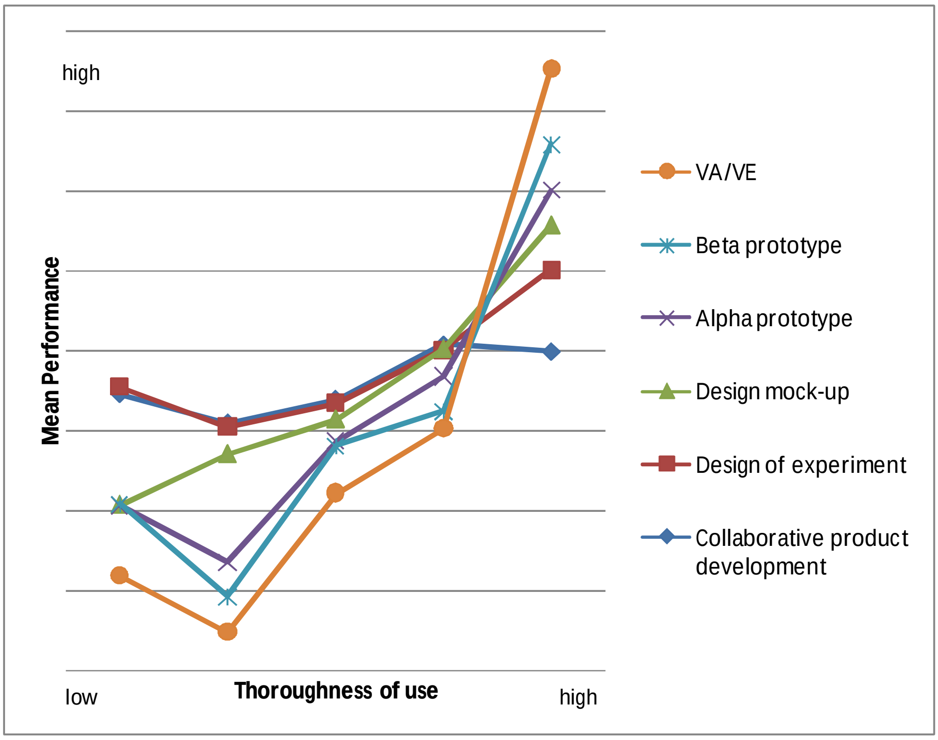
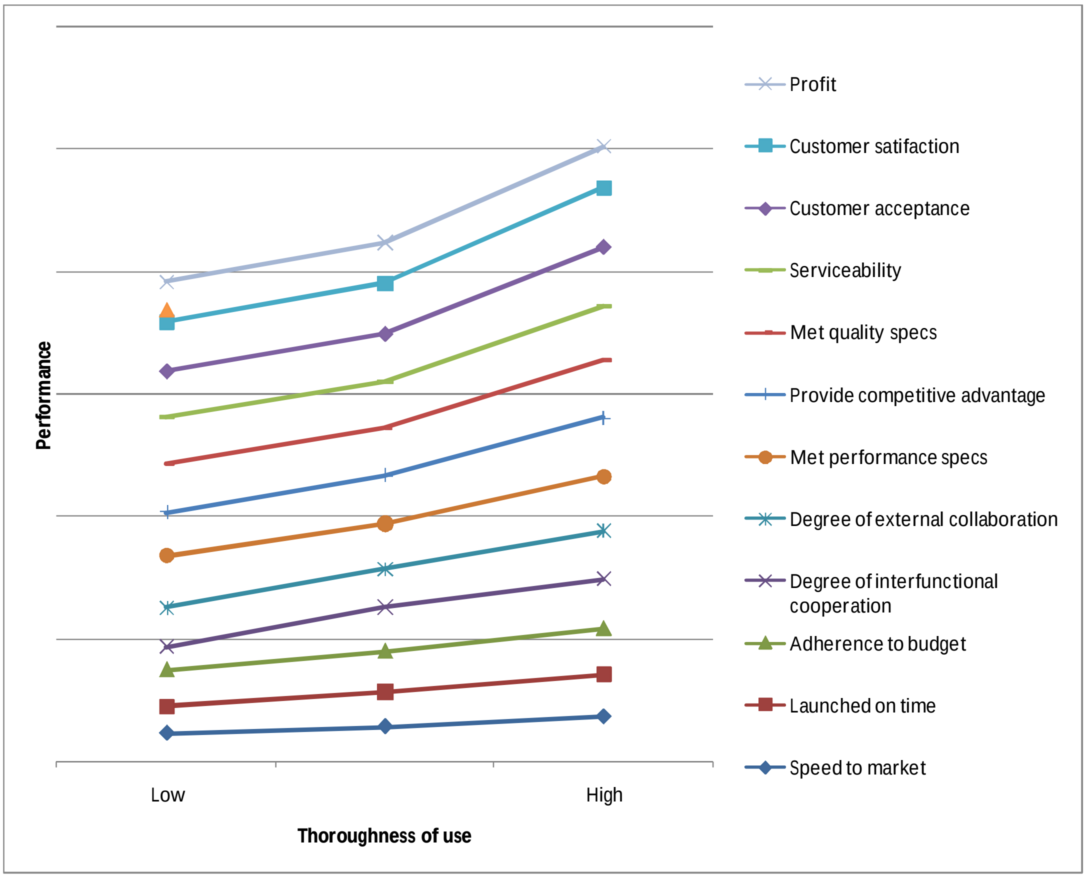


Figure 33. In-market testing: thoroughness of use vs NPD performance



5.2.16 Tool Categories - the Impact on NPD Performance

The question arises how the tool categories that belong to the 12 NPD perspectives relate to each other and how each category contributes to NPD performance as a whole. A first observation, from Table 21 and Table 22, is that no definitive patterns emerge indicating which tool category uniquely or predominantly contributes to a particular NPD performance area or areas. The Design and Engineering tool category, for example, not only bears positive correlations with product performance measures (PM6 to PM11) as one would expect, but also with process (PM1 to PM5) and market (PM12) performance measures. The same is true for the other 11 categories. What stands out, however, is that some tool categories contribute significantly more positive correlations with performance measures than other categories. As is evident from Table 30 (column 1), tools in the Marketing category collectively account for 39 positive correlations as opposed to the 20 positive contributions of tools in the Product Strategy category.

Table 30: Potential of tool categories to contribute to NPD performance

Tool Category	Number of positive correlations with performance measures	Number of tools in category	Ratio of positive correlations to number of tools in category*
Marketing/Market Research	39	11	3.55
Product Strategy	20	6	3.33
General Management	15	6	2.50
Learning & Review	12	6	2.00
Knowledge Management	7	5	1.40
Creativity & Problem Solving	11	8	1.38
Engineering & Design	16	13	1.23
Team Support	5	5	1.00
Manufacturing	3	4	0.75
Risk Management	2	4	0.50
Finance	1	3	0.33
Decision-Making	0	5	0.00
* Potential to enhance NPD performance			

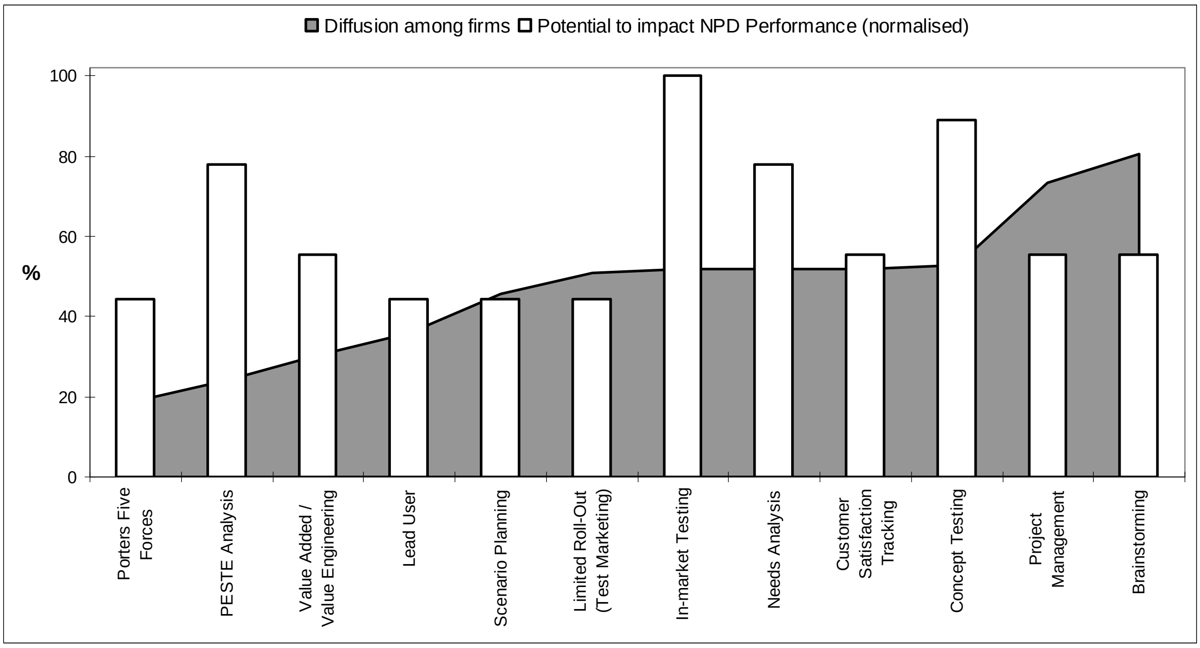
Since each category consists of a different number of tools as imposed by the research design, however, it is more meaningful to compare the ratio of positive correlations with performance measures to the number of tools in the category (see column four in Table 30). The ratios in column four are listed in descending order, implicating Market Research (3.55), Product Strategy (3.33) and General Management (2.50) as the ones that potentially contribute most towards NPD performance enhancement. Interestingly, the Design & Engineering category only features in seventh place with a ratio of 1.23, almost at a level equal to one third of the Market Research category. The obvious implication for practitioners is to pay special attention to tools represented by these higher-ratio categories.

5.2.17 ‘High-performance’ Tools

Among the 76 tools listed in Table 21 and Table 22, many tools show no correlations with any of the 12 NPD performance measures, while a few show perhaps one or two positive correlations. The importance of these zero- or low-correlation tools should not be dismissed, however, as tools often play the role of essential enablers for particular activities in the NPD process. Such tools, e.g. ‘competitor analysis’, ‘voice-of-the-customer’, ‘financial analysis’, may not bear any significant relationship with improved performance of any kind, but their use is arguably indispensable and so closely associated with specific activities in the NPD process, that they should not be omitted.

This section considers 12 tools in particular, those that yield positive correlations with four or more of the 12 performance measures that formed part of this study. Figure 34 lists these ‘high-performance’ tools against the backdrop of their mean diffusion among firm rates. The bar charts are normalised values against the nine out of 12 positive correlations obtained for In-Market Testing, which serves as the benchmark in this exercise. Six of these tools break well clear of the diffusion trend line, which implies that despite their high potential, they are currently underutilised in the small firm environment. Arguably, all 12 tools present great opportunities for those firms that are not currently using these tools and wish to improve their overall NPD performance, by adopting these tools and their associated activities in their processes.

Figure 34: 'High-performance' tools



5.2.18 Summary

Chapter 5 is a descriptive study that I designed for breadth rather than depth. It produced some novel empirical findings that have significant theoretical and practical implications for small high technology firms that I address in the final chapter, answering the 'what', 'who' and 'how many' type questions regarding factors such as tool adoption, tool determinants and obstacles, and performance impacts of tools. Armed with these insights, this chapter lays the foundations for a more in-depth qualitative study (Chapters 6 and 7) of some observed phenomena and new factors related to actual tool usage, answering the 'why' and 'how' type questions.

6 WITHIN-CASE SUMMARIES

> *"We therefore remember them [case stories] longer and understand them more complexly than had they been presented as a thin description of a construct or as a statistical table" (Dyer & Wilkins, 1991, p. 617).*

This chapter provides the within-case summaries of the five companies that formed part of the case study research. In order to resemble storytelling and to facilitate cross-case analyses in Chapter 7, I structured each case in six main areas that relate closely to the primary research questions, but because the various issues that I discuss here are so interrelated, the six main areas are not mutually exclusive.

As previously stated, this study uses a multi-case strategy researching five South-Island based companies that are actively engaged in NPD. I conducted interviews with project team members in a particular NPD project in order to understand the intricacies of tool adoption and selection, tool familiarity, motivation and use aspects. In order to protect anonymity, I only provide limited statistical and evidentiary information on the companies.

6.1 COMPANY A

Company A is typical of many technology start-ups that have their origins in a unique product idea aimed at a niche market, formed by a handful of entrepreneurial engineering students and one commerce graduate, run part-time from a home office for the first couple of years, and getting seed funding from parents. After successfully testing a few prototypes of their plug-and-play electronics security device, they started spreading the word on the Internet via forums and chat groups, selling some product in small quantities while getting useful feedback from early adopters. The small team did initial production in small batches themselves, but when sales grew beyond expectations, the company moved into commercial premises, hired more staff, and started outsourcing most of the production locally, while the core team focused on product development, project management, quality control, sales and marketing. Still today, the company regularly brings out new and improved versions of the original product concept, while also having broadened its product range. While they are in the business of inventing and producing new products and being good at it (annual turnover in the range $1 to $5 million), the company still does not have a formal NPD process in place, although they have developed very efficient sub-systems and processes for managing various aspects of NPD. The designations of the three participants are given below (initial interview times in brackets):

- Participant A1: Project Manager/Supervisor (30 June 2009 @ 4pm)
- Participant A2: Marketing Manager (30 June 2009 @ 5pm)
- Participant A3: Engineering Manager (10 July 2009 @ 10am)

6.1.1 Reasons for Using Tools

The early days were quite chaotic - "to be honest, especially the early days tend to be crisis management and firefighting" (Participant A1), "no one really knew what we were doing" (Participant A2). Still, the team was smart enough to eventually launch a successful product and build a successful company over time by continuing to develop the initial product and by introducing other product lines.

During start-up, the overriding reason for using tools was to get the job done, which was firstly to demonstrate an advanced prototype, and secondly, to fulfill some early orders and back orders for the first product release. Having received early orders based on a working prototype really put pressure on the team. Hence, the team mostly reverted to using engineering tools, and their focus was "very much tactical rather than strategic" (Participant A3). As soon as it became apparent that a saleable product was emerging, market research and marketing tools were drawn into the project. Only towards the end of the company's second year in business, having achieved initial sales and having gone through several product iterations, the need for better process and more tools became apparent. A turning point was when one day the team sat down and one member said: "Okay we need to improve our methodologies"; "we need to formalise the way we do our development"; "we do need to identify some good tools and we need to make use of them all so that the whole development process is more easily managed" (Participant A1). "So it takes some years of discipline, some years of learning and several bad experiences, before we've really taken on board that we do need a more formal and a more organised approach to doing things" (Participant A2).

Participant A3 recalls more aspects of the early days in identifying two clearly distinguishable periods in the firm's history: the first, a 2-year period that was characterised by a start-up culture with plenty of dynamism, frantic communications, trying out many things, and reactive response to some pressing unanticipated problems. Tool adoption during this period was focused on engineering tools - "the standard stuff", and marketing and market research tools, but "being a lot more dynamic on the choice of tools" in this category. This was followed by a period described as an ‘operational culture’(Participant A3), which saw the introduction of well-defined procedures and tools such as software configuration management, engineering document management, IP management and roadmapping, and a bigger emphasis placed on planning activities. Participant A3’s recollection of this change is that it was a painful shift that was, even at the time of the interview, still in process.

In summary, several themes become apparent when asking why the team in Company A uses tools. The first is effectiveness - “you simply could not do the job without some tools”. When the team initially formed, they tended to focus on the product, using tools mainly for effectiveness purposes - producing a saleable product, one that conforms to the design specifications (Participant A1). Very often, however, they would run into problems, which forced them to reactively look for tools to help them solve these “pressing problems” (Participant A3).

After some time, perhaps a couple of years, the team realised the need for working smarter, improving efficiencies - “[tools] offer efficiencies” (Participant A2). Participant A3 describes what they mean with tool efficiency, using their TRAC system as an example (TRAC is an automated online tool that creates a directory structure, a Wiki, a repository and a complete ticketing system for each new project): “automation is a huge thing in our business”; “we are not shy of putting in a lot of work to put in something that would automate the management of a particular development project”; “once it’s in [an automated tool], no matter how complex it is, then it is continuously providing value with very little input on our end, we just have to follow some basic process”. “If it scales well and there’s a lot of automation it doesn’t actually matter how much effort you put in to get it up and running.” It seems efficiency, in this context, refers to gains to be had not only within the project under discussion, but across future projects as it potentially saves many man-hours of performing manual tasks – “there’s ongoing efficiency gains and it actually lets you grow your business to the next sort of operational level” (Participant A3).

At the present time, “we can totally formalise a whole software development process to the point where everything’s absolutely perfectly managed, but it will take you forever to get anything done” (Participant A3). Instead, the company has evolved to a level where they practice agile development methodologies to rapidly develop products, using and adapting only those tools and procedures that are absolutely necessary to produce a desired outcome.

Participant A3 concludes with this statement: “Different NPD tools become relevant at different stages of an organisation’s development. For example, there are vast differences in a start-up developing a new, disruptive product and launching from scratch, to a well-established company with a portfolio of products that is looking towards implementing or improving their NPD strategy”.

6.1.2 Tool Adoption Process

When forming the company, all the members were recent graduates who brought their newly acquired skills with them, and most being engineers, the standard technical tools of the trade e.g. CAD, prototyping. These tools were automatically integrated into the company’s operations, in an unconscious manner. Only when the team expanded due to growth considerations, was the need for tools that fell outside the scope of existing members’ areas of expertise, identified - Participant A3 recalls the conversation that happened when a new employee joined the company: New employee: “Oh, have you guys got a repository?” Existing employee: “Well no, what do we need a repository for?” New employee: “Well don’t you know what software configuration management is, blah, blah, blah?” Existing employee: “Well, okay go on.” Thus over time the firm built up a toolbox consisting of tools, some of which were bought off-the-shelf, but others mostly developed in-house. A lot of the latter can be ascribed to the “ignorance” and “confidence” of the youthful team who appeared to have suffered from the “not invented here” syndrome (a general reluctance to use something that you have not created yourself) (Participant A3). Examples include smaller tools such as the development of financial spreadsheets, to more sophisticated ones such as product testing tools (these tools were readily available in the marketplace at the time).

With the realisation that more process and supporting tools were needed, came a situation with the adoption of tools that Participant A3 likens to the “cargo cult” phenomenon that originated among indigenous societies living in the southwest Pacific Ocean during the mid-20th century. For many years, these communities benefited from the presence of Westerners, but when they departed, lost the benefits. “In an attempt to attract further deliveries of goods, followers of the cults engaged in ritualistic practices such as building crude imitation landing strips, aircraft and radio equipment, and mimicking the behaviour that they had observed of the military personnel operating them” ("Cargo cult," 2009). Needless to say, just because these people “went through the motions” the desired results did not materialise. In similar fashion, team members from

Company A were saying (at the time) “yeah we need these tools, we’ll put them in place because actually it looks like in other companies, when they do this it works for them” (Participant A3). But, as it turned out, many of the systems and tools that were put in place fell short of expectation, resulting in people being disappointed and abandoning systems and tools, saying it’s all wrong, using poor results as an excuse for not using certain tools again. After some more time the same people came to realise that this thinking was wrong, that there was real merit and benefit in many of the tools and systems if only they were correctly integrated into the firm’s business systems and matched with their firm’s particular requirements.

Participant A1 describes how it came about that some tools, such as the software versioning and ticketing tools, were often introduced in a “haphazard fashion”. This meant that not everybody in the team bought into a tool or used it equally - “some people were more resistant to change than others. So things like that took time, now we’re reasonably consistent but not perfect [in the way that we are using these tools]”. Typically, factors that would determine to what degree a tool would be used included the clout of the person who initiated the tool (certain team members obviously had more authority than others did), who was managing the project, and how much pressure there was to actually comply with certain tool practices. Consequently, tools were often not used to their full potential, although “we’re getting better now, we tend to be pretty consistent now” (Participant A1).

Once the initial project stabilised in terms of established systems and tools that drove it, and the launch of subsequent projects, it is not difficult to adopt new tools into the firm (Participant A2). Weekly meetings are conducted where individual team members can express their needs for specific tools, and for those tools in the order of USD500-USD600, the go-ahead is usually given. Spending above that normally requires more justification that has to go through a formal approval process (Participant A1).

6.1.3 Obstacles to Tool Adoption

From a list of typical obstacles to tool adoption, Participant A3 selects only one: insufficient budget. Apart from acknowledging this very common obstacle, he adds that it is not the complexity of a tool, per se, that serves as a deterrent for tool adoption, but the associated ongoing management effort that is required for a particular tool. As an example, he quotes the TRAC tool that took them six months to implement and customise, but that did not put them off from adopting this tool as the team knew that once it was installed, it would need very little management effort to keep it going and produce the benefits. On the other hand, they are not keen to engage in what they call heavy weight project management as it is perceived as just too labour intensive, despite the potential benefits it may bring. This confirms the finding of 40% of firms in the survey sample (refer to Figure 23, p. 119 – not included in this summary) whose view it is that some tools are just too difficult to implement from a resource, culture and/or process perspective.

6.1.4 Tool Familiarity

During the interview the three participants were asked to rate their familiarity with the tools they used during the project on a 5-point Likert-type scale, where 1 = very little and 5 = very much. The following are the combined rating counts of two participants (one participant did not complete this exercise): 1:- 0 counts; 2:- 10 counts (‘risk assessment matrix’, ‘cross functional teams’, ‘workflow’, ‘teambuilding’, ‘computer-aided engineering’, ‘PESTE analysis’, ‘engineering document management system’, ‘knowledge management’, ‘fault tree analysis’, ‘computer prediction models’); 3:- 11 counts; 4:- 20 counts; 5:- 39 counts. This indicates that generally speaking, the two participants of Company A mostly display high levels of tool familiarity with the tools they use, achieving a total count of 59 for the 4 and 5 ratings. On the down side they obtained 21 counts for ratings of 3 (average familiarity) and lower.

6.1.5 Tool Usage

Company A is very flexible in the sense that they don’t rigidly prescribe a particular tool for a particular task. Where possible they tend to use different approaches or leverage some of the tools at their disposal to get jobs done - “we would try and adapt to what’s required” (Participant A1). For example, on occasion tools would only be used for a short amount of time “just to get things started” e.g. ‘business planning’ (Participant A3). They would spend some time together as a team devising a business plan because “it puts everyone on the same foot and even though there’s output [the written plan], the output’s useless and it’s immediately chucked into the rubbish bin”. For them the value in business planning was to get every team member thinking alike at the starting line, pointing them in the same direction and setting them off on a course of action that everybody agreed upon at that point in time. They realised that in practice things would probably turn out very differently than planned, but that did not matter as the plan served its purpose at the time - they could continue working for some time before it would be necessary to consolidate again with a next planning session.

Another example (Participant A3) of flexibility in tool use is the very innovative way in which the company modified and combined principles of ‘test-marketing’ and ‘lead user’. Initially they intentionally just announced the product on Internet chat groups based on its features, not its possible applications. Although they knew themselves what the main application and the obvious primary market for the product was, they purposely did not tell people what they can use it for, but waited to see how people actually used it. From the feedback they received, they were able to identify and scope niche derivatives of the same product for niche markets. Had they suggested applications for the product in the first instance, the company believes they may never have found out about certain other ingenious applications for their product. Participant A2 attributes this successful outcome to their flexible approach to using tools - “we’re very flexible so I don’t particularly adhere to any sort of way of working with tools”, “I devise my own methods because it does get results”.

Somewhat related to the previous example, Participant A1 recalls how they used limited roll-out to great effect – “and because we were the only ones with this product we could afford the product not to be perfect and what you would find is you would get feedback from the market, in other words they would try something on a platform that we’ve never used before”. So in a clever way they got the early adopters to carry out a lot of testing for them, free of charge to the company, and on top of that the customers paying themselves for the test models.

Due to the very small size of the company, team members were often forced to wear many different hats at the same time, putting them under huge time pressure to get a diversity of jobs done (Participant A1). Consequently, when team members were looking for tools to provide solutions to different types of problems, for example needs analysis and ethnography, they would hurriedly draw on aspects of tools that they were familiar with, not always directly, perhaps from tools that they studied at university, in ways “not quite as formal or a totally best practice approach” as they would have liked under ideal conditions. Although this approach did produce results and eventually a successful outcome, it cost them a considerable amount of money and wastage because of inefficiencies - “had we taken a more careful approach to that rather than just charging in..., ... then we would have saved a lot of money” (Participant A1). It seems team maturity, or the lack of it, at times played a part in slowing down progress: “when you come out of university you’re very gung ho, ..., no one really likes having to sit down and formally communicate, to do all the meetings. In some ways it feels like a hassle, so most engineers' natural approach to solving problems is to sit down and start coding and let it evolve from there" (Participant A2).

No formal tool training was ever provided by the company – "we used our skills from university", "and as I say learning as you go from making a lot of mistakes". "Having said that, there is some value in making those mistakes and going through that and if you're still around after some time then you're not doing too bad" (Participant A1).

For Participant A3 'thoroughness of tool use' means "the stuff that we started to focus on and integrate as part of our culture. So thoroughly being like, if the tool wasn't being used, there would be repercussions on the people who were supposed to be using it, right? Less thoroughly is that we're a bit more lax with process". However, there were other reasons for using tools thoroughly, such as instances where external demands were placed on the company. For example during start-up when the company applied for various development grants from government institutions that necessitated very thorough preparation of a feasibility study, business case and marketing plan.

Yet another example of a tool that was very thoroughly used is the TRAC system, a tool that today is very much integrated in the company's culture. The original tool was bought off-the-shelf, but the team decided to customise it by adding extra features and functionality "to better fit in with our culture", "customisable tools are fairly important, you've got to be able to kind of sometimes fit a square peg in a square hole, but all you got is round tool, and you've gotta shape it a bit so it fits in that square hole" (Participant A3). It was very important to the company that this tool was correctly used by everyone, so they made a great deal in getting all team members up to speed with it. Unfortunately, there were some problems with this tool that caused a huge amount of frustration among team members who often wanted to revert to "the old way of doing things". The proponents of the tool, however, kept working on solving the problems and trying to "entrench it in the culture" of the firm. Eventually the problems were sorted out and the tool started to prove its value, but still the challenge remained for a considerable amount of time to completely win over some skeptic users and make them fully accept this tool. Some people actually never accepted the tool and left the company as a result. Reflecting back, "it was just painful and it almost caused us to throw the baby away with the bath water" (Participant A3). Today this tool is part and parcel of daily operations, but the lesson learnt is that when a new tool is introduced, as far as possible it must be faultless and fully tested before rolling it out for widespread use, otherwise it can create plenty of unhappiness and even cause people to leave the company.

During the interview the three participants were asked to rate the thoroughness levels to which they used their tools during the project on a 5-point Likert-type scale, where 1 = superficially and 5 = substantially. The following counts were obtained for two of the participants for each of the five ratings: 1:- 1 count; 2:- 15 counts; 3:- 14 counts; 4:- 27 counts; 5:- 22 counts. Sixteen tools received 2-ratings and below (indicating superficial usage), which could be of concern. They were 'design mockup', 'roadmapping', 'engineering design management system', 'knowledge management', 'project intranet', 'configuration management system', 'computer prediction models', 'design review meetings', 'stage gates', 'alpha prototype', 'scenario planning', 'concept testing', 'financial analysis', 'concept statement', 'teambuilding'.

6.1.6 Tool Experiences

In hindsight, Participant A3 thinks the company did very well in commercialising and launching the product despite the huge drain on resource caused by R&D. He attributes some of this success to the clever way in which they used Internet tools for doing market research and selling the product. Participant A1 agrees: "What we found for these types of devices [innovative technology products] is that there is always a significant portion of the market [early adopters] that's prepared to pay whatever price because they just want to buy the latest technology".

Participant A3 also gives a lot of credit for their early success to some of the sub-contractors they worked with in developing innovative solutions to technical problems – "And dragging those guys in, coupling their knowledge with our knowledge", they got it right, "for several years it gave us a real competitive advantage, but we wouldn't have got that if we actually didn't drag those people in...".

One aspect of the business that did not go that well was budgeting, or rather, the lack of it. Had they devised a budget, actual spending would have exceeded it as the general consensus is they spent a lot of money during those early days (the project manager scored 'adherence to budget' a very low 1 out of 5). Other areas of average performance include 'speed to market' and 'launched on time', both receiving performance ratings of 3 out of 5. Participant A1 offers two possible explanations for his team not making deadlines. The first is to do with the huge uncertainties and risks involved in developing highly innovative products – "then of course estimates are always going to be very fuzzy because you have not done anything quite like that before". Linked to this is the tendency for people to be naturally optimistic, "which is a good thing in many cases, but usually in terms of hardware and software development is a bit of a flaw". The second factor causing delays is when the team does not focus on one project at a time – "so you might have made your deadline had you been able to just focus on that one development [project]. But often we were loading up our principle people with too many little bits and pieces. So we would start them on a new project but of course, modifications, bug fixes and so on from the previous project was still taking up a lot of time." To improve the time-estimate problem, Participant A1 suggests, "it certainly comes back to a more formal approach. You should spend more time in the early design phases to really carefully lay out what you're going to do. Do proper feasibility studies, maybe even look at building prototypes, basic concepts to test them in the early phase, if you put that time up front you will be more accurate in how long it's gonna take and you'll probably be in a much better position to do that".

Participant A1 describes a problem that they encountered with a particular tool, Microsoft Project. "We've found in our project the level of uncertainty is so high you'll do a task breakdown and then within a month of starting work on the project, the actual tasks and the time they take have changed so markedly that we've found it to be of limited value." In addition, as Participant A3 mentioned earlier, the ongoing management effort required by this software was considered too big for this particular project, and the tool was subsequently dropped – "we tried it, we gave it a good crack to see if it actually gave us the value…, but found it didn't" (Participant A3).

6.2 Company B

Company B in its current form was incorporated in 2000 with the merger of two companies. At the end of 2008 the company moved into a bigger building and acquired more advanced machinery and equipment. Their primary businesses is tool and die making, precision engineering, and original equipment manufacturing - doing mostly contract manufacturing jobs for industrial customers, supported by in-house design capability. Over the past decade, the company has engaged in collaborative product development of several industrial products of its own, and most recently a state-of-the-art newspaper-wrapping machine (the focus of this study and the company's first complete product). The company initially bought the intellectual property rights from a Christchurch individual who designed, manufactured and sold approximately 40 units of the original device in New Zealand. Over a period of twelve months, the company completely redesigned and professionalised the original ‘cottage industry’ design, added new features and functionality, and set up a sophisticated manufacturing system. Most of the manufacturing is done in-house, although things such as laser cutting, plastic folding, sheet metal work and folding work are outsourced. The bulk of this work was done by a young engineer who basically worked full-time on the project, supported by three to five factory staff where and when required. By mid-2009, the company has sold a dozen of the new model into Australia. Though the company has no formalised NPD process or innovation strategy in place, it recently developed a comprehensive Strategic Plan / Business Plan and formalised an ISO9002 Quality Management System. Annual turnover falls in the $1-$5 million band. The designations of the three participants are given below (initial interview times in brackets):

- Participant B1: Engineering Administrator/Project Manager (16 July 2009 2pm)
- Participant B2: Manufacturing Manager (16 July 2009 3pm)
- Participant B3: Managing Director (16 July 2009 4:15pm)

6.2.1 Reasons for Tool Use

Because of immense time pressures to complete the first prototype on time for an exhibition in Melbourne, from day one there was a very strong task focus and urgency among team members to get an advanced model of the final product ready - “time constraints were a big thing” (Participant B1). “We gotta use our time wisely and so sometimes I guess we do have to spend more time on it [tools], but we just have to get on with the job” (Participant B2). Even after the Melbourne exhibition, time was always in short supply as the company had to chase back orders received at the exhibition and elsewhere.

As the original product was already in the marketplace, the team approached this development project “a little bit different from say a completely new product” (Participant B3). Participant B3 believes that formality normally has its place, but in this particular case, there was perhaps less of a necessity for it – “in this particular case we could see that there was a very immediate opportunity, particularly in Victoria, and if we wanted to capitalise on it we needed to move quickly”. Very little planning was done ahead of the project start and tools were called in mostly to help get an immediate job at hand, done. Team members intuitively knew which tools to use as they carried out different activities - “as an engineer you just tend to use it”

(Participant B1). The word “intuitively” popped up several times during these interviews. The scenario in which this project played off was mostly a situation where very little prior consideration was given to which tools to use at what stage, or why - “it’s not like I set out [afore hand] and said, Okay, we’re going to use this tool, we’re going to use that tool. I guess [things] happened automatically” (Participant B1). At times, when problems arose, the team would resort to whatever tool was needed, off-the-shelf or custom-made, to solve it - “wherever there’s a bottleneck, we sort the bottleneck out and there’s obviously the next bottleneck”, “so whatever is the highest priority we adjust, if it’s an Excel tool that we can put in place to sort it out, or if it is a physical bench on the floor, ... [we take] one step at a time” (Participant B2). When solving one-off problems, a tool would be used only to such an extent that it provided answers/solutions to the particular problem, not necessarily, beyond what the tool was capable of (e.g. design for manufacturing) “but yeah, most [tools] we used in some limited way” (Participant B1). At times, tools that may potentially have added value (“e.g. finite element analysis”), but were seen to be not critical to task completion, were not used, thus saving time - “it can sit on the shelf until I need to use it” (Participant B1) - and cost “whatever money you want to put to it [tools] and what is the best use I can make of this hour” (Participant B2). Thus, while the particular nature of this project and tough delivery schedules in many ways justified the often ‘superficial’ use of tools, it did not mean team members were necessarily satisfied with the situation - “but don’t get me wrong, often I wish we could do it more thoroughly because I think we should be resourcing ourselves better so that we can do some of these things more thoroughly. So it’s not as if I am satisfied with the degree to which we use all these tools” (Participant B2).

From the above it appears that, in addition to this particular team having had clear reasons for why they were using tools, they also had reasons for not using it. “You can have paralysis by analysis and that’s certainly not what we’re about” (Participant B3). The same person suggests reasons for use being “it provides checks” and “it avoids the risk that you rush into something that you have not appropriately researched”, “so it does have its place”.

Amidst the intuitive approach followed by Company B, Participant B1 acknowledges that tools “give you a way to objectively measure where you are, or to direct you rather than just relying on your instinct”. It appears that some users used tools to provide them with some certainty and direction at times that were characterised by plenty of challenges, uncertainty and risk. As new orders for the product were processed, ongoing procedural improvements were introduced and more tools were brought into the process to drive efficiencies and effectiveness. What underlies this is a strong company culture that encourages ongoing improvement (Kaizen) and the company image that has always represented high quality work and service (Participant B2).

6.2.2 Tool Adoption Process

Since NPD is a very small part of the overall business activity, Company B has not considered it necessary yet to devise a particular NPD process. Consequently, for the project under review tools have been drawn on when a particular activity called for it - “we didn’t sit down a lot and think about it” (Participant B1), “I mean it’s just a case of what’s appropriate” (Participant B3). Some tools (e.g. Kanban, CAD and configuration management system) were driven by normal firm operating procedures that are closely integrated and associated with component design and manufacturing activity, while other tools were driven, but not necessarily prescribed, by culture, e.g. ‘quality control’ - “while some tools are driven by paperwork and procedures, others are driven by a culture of continuous improvement” (Participant B2). ‘Quality control’ is a tool with many aspects to it - “it’s a matter of just reinforcing these things all the time until it becomes a culture in the shop” (Participant B2). Therefore, instead of formally prescribing various tools and principles related to ensuring a high quality of workmanship, e.g. ‘continuous improvement’, ‘tool storage’ and ‘workplace cleanliness’, Company B established a code of workmanship that compels factory workers to use these tools to the best of their ability. A general rule of thumb is that for tools linked to procedure, management “can be more autocratic and just enforce it” while for tools linked to company culture “you got to kind of get buy in from the guys because you got to get the people to do it” (Participant B2). For example, for more wide-ranging tools such as ‘lean manufacturing’ and the ‘seven steps to world-class manufacturing’, the company’s adoption approach is to slowly expose staff to some of their principles “we are on the quiet bringing things in”, and when the time is right, when their practice has somewhat infiltrated company culture, follow a more formalised approach to enforce more comprehensive use of these tools – “I’d like to make it much more formalised that everything we do we measure it on those principles” (Participant B2).

6.2.3 Obstacles to Tool Adoption

In the online survey, Participant B1 pointed out ‘insufficient budget’, ‘the value of the tools is unclear or not well enough explained’, and ‘lack of awareness’ as potential barriers that may have prevented Company B from adopting more NPD tools in developing the product.

At the time when this particular project was started, the company just moved into a new facility and bought some new machines, which put a considerable strain on financial resources. Consequently, there was always going to be strong constraints placed on the acquisition of tools for this project - “so at this stage most tools are just, it’s nice to have, we’d love to have it, it would make things better, but we need to just establish the cash flow and get us in a good space so we can weather the risks of the future” (Participant B2). Even though this company has been in business for several years, because of the said changes it found itself in a situation similar to many NPD start-ups where any spending had to be very well justified.

Two of the participants identified a number of interrelated obstacles to tool adoption in Company B. Participant B3: “The current sort of economic climate is postponing that investment [for an ERP system]. The other part that we are having problem with is actually identifying something that is suitable and affordable for an enterprise of our size, and it is a very big commitment to make because once you’ve selected a system and bought in to it so to speak it’s a major lock-in and there are some folk that have picked up on one system or another and have not had the most delightful experience with it. So yes we know that our internal systems will be much enhanced by having an ERP system but we’re also wary of getting the wrong one.”

Participant B2 indicated that the right timing and sufficient management capacity for introducing a major new tool, or rather the lack of it, have shown to be an obstacle to tool adoption. Since the introduction of major tools often requires intense management with regard to preparation, training, testing, implementation, etc., a suitable period of time must be found that fits into people’s schedules, when most people will be able to attend training and help with the implementation, and a time when workplace interruptions are at a minimum. Participant B2 is very clear on this issue: If the capacity to manage a tool is not there, don’t bring it in. He cites the adoption of lean manufacturing as an example of a tool currently on hold because during the year key people were not available at critical times. Another key aspect of tool adoption is the ability to keep momentum once it has been introduced - “When you start you need to keep that momentum going. Lose the momentum and that’s the worst thing in management. Not just that, the guys on the floor lose respect for any new things you implement. So I often hold back on things just because I know we won’t be able to follow through with the momentum.”

6.2.4 Tool Familiarity

During the interview the three participants were asked to rate their familiarity with the tools they used during the project on a 5-point Likert-type scale, where 1 = very little and 5 = very much. The following are the combined rating counts of two participants (one participant did not complete this exercise): 1:- 3 counts (scenario planning, needs analysis, teambuilding); 2:- 1 count (financial analysis); 3:- 5 counts; 4:- 16 counts; 5:- 2 counts. This indicates that generally speaking, the two participants of Company B mostly display high levels of tool familiarity with the tools they use, achieving a total count of 18 for the 4 and 5 ratings. On the down side they obtained 9 counts for ratings of 3 (average familiarity) and lower.

6.2.5 Tool Usage

The development of the product was in the first instance driven by a clear set of product outcome objectives by the Managing Director that he compiled through market research, and talking to end-users (Participant B3). "The one thing he [the MD] was dead set on was that we have a modem in the machine" (Participant B1). In addition, the core development team included more ideas for improvement from brainstorming sessions, drawing from their experience in other areas - "we put in a control so that the amount of plastic usage that the machine uses to roll each paper can be adjusted depending on the size of paper they are wrapping, I used my idea pulling from my background in material ..." (Participant B1). Last, but not least, the strong culture of quality workmanship played a huge role in determining the final product - "[Company B] has a particular standard of quality that it wants to portray [through this product]" (Participant B1).

Thus given the original machine (the old version, with an outdated set of drawings), a set of development guidelines and tight deadlines, the team set off to develop the new and very much improved wrapping machine. During the first several months, Participant B1 used 'CAD' extensively to produce a full set of new drawings, which included many design changes and principles of design for manufacture. He also devised spreadsheet-based systems indicating all part numbers (~330 parts) and a comprehensive bill of material, and for scheduling activities. During the development process, as project leader and the only person assigned to the project in an almost full-time capacity, Participant B1 took it one day at a time "filling the blanks". When needed, he would consult other staffs who were mostly working on other manufacturing jobs and managerial tasks. Others were involved, but not assigned to the project, e.g. manufacturing and contractors. “We would try and do most of our meetings stand up if we can and not too formalised. I’ll call the contractor and get him down here and talk about whatever he’s doing, what we want to do, what we need to achieve...” (Participant B1).

As Company B very much resembles a shop floor, most manufacturing activities are driven by lose-standing, but formal, independent procedures (e.g. material ordering, quality control, job scheduling, document control) – “we make sure the whole process the component goes through is documented. We try to minimise the verbal, although we encourage communication, we minimise any verbal communication. If you can’t put it down on paper what you want it’s very hard to measure and that just causes interruptions” (Participant B2). Most peripheral activities such as ‘needs analysis’, ‘risk management’, ‘decision making’ and ‘scenario planning’, on the other hand, were done in a very much less formalised manner - “because we don’t do that much product development we don’t have much set in the way of how we develop the product. We just go for it in the Kiwi way” (Participant B1), “we constantly have to make those decisions without actually doing a matrix”, “we once again would do this on the fly and just discuss it [among ourselves]”, “I use it [scenario planning] all the time in my head, whereas people I guess who use it substantially would actually use a tool and sometimes write down all the options” (Participant B2), “I was able to quite quickly ascertain that yeah there was a potential for the product”, “we didn’t feel as though there was a need to be overly structured I suppose in this particular case ...” (Participant B3), “we really don’t apply tools in a rigid way, just intuitively using [them]”, “we kinda throw away the tool book” (Participant B1). Participant B2 summarises the overall situation quite well in saying “I think that we’ve kind of just stolen the principles of these things [tools such as ‘theory of constraints’ and ‘lean manufacturing’] and if it makes sense we run with it. So we haven’t gone according to certain rules or certain procedures”.

It furthermore appears that activities that were directly related to adding value to the product (i.e. manufacturing), were far more formalised than the ones that were not directly saleable - “we got to use our time wisely and so sometimes I guess we do have to spend more time on it [activities and tools that add indirect value], but we just have to get on with it [the physical job of manufacturing - giving it priority]. I guess it comes down to costing, you got an hour it’s worth fifty or a hundred dollars, whatever money you want to put to it and what is the best use I can make out of this hour, and so if you do use something or do something [like using a tool and adding indirect value, but non-billable] I guess you got to decide how, in what detail you're going to do it" (Participant B2). Tools were not consciously thought of - "we don't think about it ... according to experience in the industry we know we need to do certain things, we need to make sure our backs are covered a little bit from a financial side and then do things sensibly from a technical side" (Participant B1).

Team members often customise tools to better suit their requirements - "we're just looking at TQM, we don't follow a prescription, we absolutely adapt it to suit...", "a lot of the tools that I implement I've used or at least studied them in the past. So when I use them I develop them to suit our needs" (Participant B2). Participant B2 goes on to explain how they adapted the use of Kanban and how well it was working for them. Tool modification is in the order of the day - "This is part of the way you do things. It [the tool after modification] becomes our tool, the tool doesn't have a name like this, and it just becomes part of [Company B's] procedures".

Participant B2 believes management sees its employees as its greatest tools – "I think that's one big thing, I guess our people, making the right choices who we employ". To ensure these 'tools' are used to their fullest potential, the company cultivated a culture that is driven by five specific values or principles: honour, integrity, care, flexibility and continuous improvement. It is very important for Company B that staffs adhere to these principles in everything they do, which include the application of tools. Participant B2 explains that while it can be said that paperwork (which is integral to many company procedures) to some degree enforces the use of certain tools, for example carrying out quality control procedures, it could be technically possible for a person to use the tool (tick all the boxes) but not do the actual activity with a great deal of integrity (skip aspects of it, or be careless in carrying out certain tasks). As it would be very difficult to police the way people use tools, the company relies heavily on this set of values and their pride in the quality of their work when people carry out their tasks.

During the interview the three participants were asked to rate the thoroughness levels to which they used their tools during the project on a 5-point Likert-type scale, where 1 = superficially and 5 = substantially. The following counts were obtained for the three participants for each of the five ratings: 1:- 7 counts; 2:- 13 counts; 3:- 18 counts; 4:- 11 counts; 5:- 10 counts. Twenty tools received 2-ratings and below (indicating superficial usage), which could be a concern. They were 'design review meetings', 'stage gates', 'scenario planning', 'financial analysis', 'quality function deployment', 'design mock-up', 'value added / value engineering', 'needs analysis', 'design of experiment', 'computer-aided design', 'process flow', 'brainstorming', and 'feasibility study'.

Although no formal budget was set for this product, the general feeling among management is that the company has spent roughly 50% more on it than what was anticipated. So it comes as no surprise that the performance measure 'adherence to budget' only gets a 1 out of 5 rating. As a general tool, 'financial analysis' scored very low in both familiarity and thoroughness of use ratings, so this is one particular area that could be improved upon. At the start of the project no formal launch date was set for the product, but the team has done very well in meeting deadlines, such as the trade exhibition for which they had to have the first working prototype ready.

6.2.6 Tool Experiences

The fact that most of the product's manufacturing is done in-house has had some benefits and disadvantages. On the downside, because machinists have intimate knowledge of the product, they may sometimes be inclined to take short cuts on certain parameters such as surface finish, as they think it is a purely cosmetic specification that may not even be visible from the outside, or take shortcuts on a very tight tolerance that they think won't affect the performance of the product (Participant B2). To address this problem, and as person in charge of quality control, Participant B2 ensures that each drawing (prepared by Participant B1) has a process sheet attached to it and gets signed off when the job is completed. The positive spin-off, though, is when the designer sometimes "goes a bit overboard in his drawings and they [the machinists] kind of, if they had to follow that strictly they might end up taking twice as long to make the component. So it works both ways, in the end [the designer] is forced to change his drawings to accommodate manufacturing, making it simpler" (Participant B2). So it comes as no surprise that Participant B1 rates the degree of inter-functional cooperation at 5 (excellent).

In hindsight, the project manager believes a number of things went particularly well for this project: internal and external collaboration, the Pathway to Market initiative of the NZTE (which essentially opened the door for the company into Australia), appointing a sales representative and service agent in Australia, and the fact that the product has been well-received by customers. With regard to external collaboration, Participant B2 adds that basic goodwill by everybody involved played a huge part in performing well in this area - "Our company is very much focused on networking and fostering good relationships and communication and we don't treat our suppliers harshly. When they're late I guess we explain to them how that affects us, but we don't jump on them, because we are so dependent on them, on our suppliers and when they do something good we try our best to commend them. Our suppliers are as important as our customers and we try to treat them in the same way. That helps a lot, when timelines are tight, this approach can pull some miracles off". "We do have a culture here of working together with our suppliers because their expertise can become our point of difference and it's very clearly evident in this project" (Participant B3). "I guess the team, we have all recognised each other's skills and even the contractors, two contractors particularly we use, our electrical and pneumatic contractors. I recognise they have more ability than me in those areas and so there's some great collaboration there" (Participant B1).

Other success contributing factors include "being reasonably successful in understanding what the customer requirement was for the product, and having had a good understanding of what our competition was and where we stood in relation to that, both in technology and value. And then taking in information and developing the product as we have. There's no doubt that using computer-aided design has been a wonderful asset to the whole programme compared to what was prevailing previously" (Participant B3). But perhaps most important was the excellent team work and collaboration with suppliers, which included the ongoing support of the original innovator – "so by consulting him along the journey just gave us the reassurance and confirmation that our ideas were merit worthy" (Participant B3).

In terms of problems experienced during the project, it appears that support systems were mainly at fault: "I'm forever trying to chase information and we're doubly entering data and everyone's entering the same thing, at different stages", "basically we got a manual ERP system that relies on all this data entry" (Participant B1). The managing director confirmed that procuring an advanced ERP system was definitely on the agenda.

Participant B2 suggests a potential shortcoming of the product lies in its integral design architecture, at least in the way the final product is offered to the market: "We have one machine that has all the bells and whistles, but what I guess is our problem is that we haven't offered alternative solutions to the customer, I guess that will still come." He compares the current model with the top of the range Mercedes Benz, and recommends that the company should "be offering the cheaper A-series Merc for the lady who just wants to drive her kids but wants to have a Mercedes". He acknowledges that this will take time and while they are currently focusing on getting their manufacturing up to speed, that they have come a long way in "getting our systems and processes in place" so they are well-placed to build any new products in future.

Another inevitable problem facing Company B, like so many other small NPD firms, is having to rely on very few people within the company to get the job done. The project manager, for example, has to wear many other hats such as engineering manager, design engineer at the same time (Participant B2). On top of that, other tasks also pop up unexpectedly for the project manager, such as the recent commissioning of two machines in Perth, Australia. This makes it difficult for people to focus on specific aspects of the job, but fortunately the project manager "is a good planner and a good organiser and cares a lot for what he does, so he takes responsibility for it" (Participant B2). As this particular commissioning exercise transpired, it was necessary to incorporate special, but unplanned design changes for the customer to enable the handling of larger papers. Fortunately, Company B's systems were flexible enough to cope with this request. This could be a forerunner to offering the product in more modular format to potential customers.

"So yes, it's been a bit of a journey, it's taken a bit longer but we've had a good outcome. And that's in the end what counts the most" (Participant B3).

6.3 Company C

Company C is a wholly owned subsidiary of a larger privately-held technology research company. It was founded in 2005 to take a product suite of medical measurement devices to market. The core technology of the product, which offers significant improvements over existing products, originated from its own R&D and in-licensing, and design and prototype development were all done in-house. At the start of the project, the project manager put a custom-designed NPD process in place to guide the concept through four design stages and one concurrent product & process verification and validation stage. As the focus of Company C was on the development of a single suite of products, no formal innovation strategy was deemed necessary. While manufacturing and assembly are outsourced to local contractors, quality assurance is done in-house. Because of the medical nature of this application, the industry watchdog imposes strict development practices and quality requirements on the suite of products. Frequent end-user inputs and trials throughout the project were also compulsory. Apart from a very professional product development team that was clearly committed to good practice in all aspects of the project, a lot of the good practice observed by Company C was 'enforced' by external factors such as regulatory controlling bodies. A core cross-functional team of 12 people worked full-time on the product suite, which included specialists in electronics engineering, software development, a dedicated project manager, and a marketing manager. While the suite of products is also marketed in New Zealand, the bulk of its undisclosed earnings to date come from exports. The designations of the three participants are given below (initial interview times in brackets):

- Participant C1: Project Manager / Product Development Manager (28 May 2009 4pm)
- Participant C2: Marketing Manager (5 June 2009 12:37pm)
- Participant C3: Software Team Leader (5 June 2009 1:30pm)

6.3.1 Reasons for Tool Use

One of the main reasons why Company C uses tools stems from the specific nature of their products, which is medical. As such, external controlling bodies in the Medical industry impose many compliance factors on product developers to ensure health and safety issues of patients on which the products are to be used. For example, in this instance developers must conform to the quality standard ISO 13485 and other rigorous processes including 'risk analyses', 'design review meetings', 'configuration and change control'. Since the USA is one of its major markets, Company C has to comply with strict import regulations imposed by the FDA. At the start of the project, Company C therefore had a clear mandate of the tools that were mandatory for this particular product.

Another important reason for reverting to tools is to do with improving process efficiencies - "... because a tool is there to help you reduce your cost and reduce your risk and reduce your time for development" (Participant C1).

Company C has a strong task focus - they know exactly what needs to be done and then go after it in the most efficient way, nothing more, nothing less - "we only used the tools that were necessary to achieve our end results. We didn't use tools just to make a point"; and "... we all used tools as a means to an end, to get a quicker result" (Participant C1). Some tools, especially the more technical ones, are internally mandated and so intrinsically linked with certain activities that getting the job done without them is impossible. On the other hand, there are "a whole raft of other tools floating around that some individuals will choose to use and some won't" - (Participant C3). It turns out such 'optional' tools are not critical to the successful execution of the project, but they are still deemed valuable as they add value in one way or another.

For Participant C2 (a marketing professional), the use of tools was essential to assess the market and determine appropriate market entry strategies for a product for which no benchmark data existed at the time (the product is categorised as a radical innovation). In addition, she believes tools are useful in creating a common language among team members and serving as a common platform that provides a systematic way for functioning and working as a team.

6.3.2 Tool Adoption Process

According to Participant C1, adopting tools into the company is not difficult as "we make the system work for us", "we always look for new ways, especially because we are now doing software development, software improvements. We then draw that in and see how we can apply that and then we change our internal processes, and we also adapt what we see, to our services". Two out of the three participants say they purposely consider the potential benefits and disadvantages of a tool prior to using it.

Company C's particular outsourcing business model (apart from design work) necessitates tools that can help them manage the supply chain - "we have our own little system which is on Excel which is not very successful, but we are still looking for an inventory management system" (Participant C1). Thus, while many tools were developed and customised to the firm's very specific requirements in-house (e.g. 'quality analysis', 'marketing plan', 'comparative pricing models'), others were purchased off-the-shelf (e.g. 'bug tracking') (Participant C2). "Creating my own 'quality scale' I needed to do it for myself because it applies specifically to the market and so I just gave it a rating score and had to use my own thoughts as well and analysis to generate this scale. So this knowledge can't be purchased, it needs to be directly applied" (Participant C2). "We've got a whole raft of internal tools that we've written ourselves to automate things", "it's often quicker to develop something rather than take something generic off the shelf and configure it to do what you want it to do" (Participant C3). As needs for new tools are identified by individual team members, brief motivations for tool acquisition are provided to the project manager and usually granted, if not excessive in terms of cost - "we decided as a team that we needed to do more customer satisfaction tracking..., ...so it's come from us, generating this need and then moving forward" (Participant C2).

Company C, under the leadership of the project manager, initially introduced a formal NPD process. The process is constantly under review and streamlined to better suit the firm's requirements – "we recently changed our development process" (Participant C3). The fact that the process is clearly defined and formalised does not mean that the team members vigilantly stick to the letter of it – "the project doesn't kind of move from here to here, it's more a sort of a continuous thing, if that makes any sense" (Participant C3). A formal process also does not imply the company has a 'formal tool system'. In other words, individual internalised tools are not necessarily formally linked to specific steps in the NPD process (Participant C1) or to specific phases in the process "So it's not like in one particular phase you will use this and you will use that [tool]. It's more like we use a range of tools and basically use them across phases through development" (Participant C2). It appears some tools exist at an "ad-hoc" level "they're just floating around on thin air" - a level where it is optional to use tools – while other tools are well integrated into organisational processes (not necessarily the NPD process) (Participant C2).

From a regulatory point of view, the team always knew exactly which tools they had to adopt, e.g. 'voice-of-the customer', 'in-market testing', 'documentation control', 'risk analysis' (Participant C1), but in addition, they are constantly looking at new and better ways of doing things. The company is in a fast-growth stage where systems are ever changing and developing, and "tools are following suit" (Participant C3). Team members stay on top of which tools are available by attending government-funded training courses and attending networking opportunities run by organisations such as Export Canterbury and public relations consultants. The company itself does not provide specific tool training and relies on its employees to draw on their prior knowledge of tools gained during tertiary studies or previous jobs, and self-learning to get up to speed with the tools they use.

6.3.3 Obstacles to Tool Adoption

In the online survey Participant C1 pointed out ‘insufficient budget’, ‘too difficult to implement from a resource, culture and/or process perspective’, ‘requires too much training’ and ‘lack of awareness’ as potential barriers that may have prevented Company C from adopting more NPD tools in developing the product. Apart from these, Participant C2 singles out monetary and associated costs as important barriers to tool adoption. This affect the way that spending is prioritised among different things: “We want to spend money on other things, not tools basically because although it might help your process it’s not going to make your product more flashy or get them out to more customers. There are other priorities basically for money”. The participant continues to say that establishing tools in a more systematic way requires “a lot of time and energy and effort”, resources that are typically in short supply.

Interestingly, tools perceived as having the potential to extend the product development time or having a high degree of complexity, are intentionally pushed aside - “so you wouldn’t use a tool that was going to extend your time”; “... we wouldn’t consider that [such tools]”. When the interviewer raised the possibility that such tools could have potential benefits for the project, perhaps at a stage further down the line after the product was launched, the response was still negative - “no, we wouldn’t consider that. We would keep that tool in mind for training purposes when the pressure is off”. It seems that due to severe time pressures practitioners are willing to trade off the potential for longer-term benefits against almost-certain time-to-market gains.

6.3.4 Tool Familiarity

During the interview the three participants were asked to rate their familiarity with the tools they used during the project on a 5-point Likert-type scale, where 1 = very little and 5 = very much. Overall, there were no counts for the 1 and 2 ratings, while the 3 rating (average familiarity) only got 3 counts, all for different tools: ‘Concept testing’, ‘change control system’, and ‘workflow’. The 4 rating got 10 counts, and the 5 rating, 25 counts. This indicates that generally speaking, the three participants of Company C display high levels of tool familiarity with the tools they use.

6.3.5 Tool Usage

The first tool that the project team internalised was their current NPD process which they customised onto a spreadsheet in accordance with the firm’s size and the product under development, using generic templates. The original process had very longwinded release mechanisms for hardware and software at the same time through different phases, which were subsequently streamlined (Participant C1). Together with the evolving process which described the various input and output phases, right from the start the project team did very thorough planning which included aspects of an ISO 13485 quality assurance process, a project plan, a business plan, and a cost plan – “the project management process that we use, that was to get an organised structure into the development of the product” (Participant C1).

Some tools that have been introduced early in the project have been observed to evolve over time as users became more competent and found better ways for the tools to deliver intended results – “we’re getting more detailed and more comprehensive in our road mapping from when I started”, (Participant C2). Other tools have been combined into one – “we have a software basically that’s used to track bugs in software development, and we often input customer feedback into this programme as well and take that into account in product development” (Participant C2). In addition to developing its own tools (e.g. ‘license tracking’ tool, Excel spreadsheets, ‘automatic code generation’), the company uses a number of commercial and opensource software packages, which often do not meet the company’s requirements fully. While it is not easy to change the base functionality of these tools, it is sometimes possible to make subtle changes to what these software packages can do, and in other cases, it is possible to buy additional add-ons to provide extra functionality (Participant C3).

Because of the niche nature of the product, it was not uncommon for team members to develop their own spreadsheet-based niche tools, e.g. ‘comparative pricing models’ – “Creating my own quality scale I needed to do it for myself because it applies specifically to the market and so I just gave it a rating score and had to use my own thoughts as well and analysis to generate this scale. So this knowledge can’t be purchased, it needs to be directly applied” (Participant C2).

The software team has so-called ‘ten minute catch ups’ three times per week where everybody is free to say what he or she wants. At these informal meetings the team usually goes over what people have been doing and discuss any difficulties anybody's had (Participant C3). Other teams have similar daily stand up meetings that serve as informal forums where problems are solved. Although there is no formal way of telling people about new tools to use, these meetings are ideal for talking about tool issues (Participant C1). Despite its overall small team size, at the project level Company C follows quite a formalised communications approach where they have collaborative cross-functional meetings once a week during which project issues are discussed by members from systems engineering, marketing, software, and of course the project manager (Participant C2). Yet another sign of formalisation in this company is that most changes to tools are normally officially documented – "yeah they are all formally documented. They need to be, you know we've got standards that we need to adhere to, so we basically track it in this software system and that's all written down, everything, it's required" (Participant C2).

When applying tools, team members tend to rely on their own interpretation of how a tool should be used – "we didn't go out and read out how you should use these tools. We just used tools that we knew of" (Participant C1), "[the way we apply tools] is far more intuitive, absolutely. It's because we don't have experts for example in customer satisfaction tracking or anything like that, we are more rounded individuals and although we're not experts in these tools we know how to intuitively use them, to a certain degree" (Participant C2). Another factor contributing to this observation is the tendency for members in relatively small teams to perform multi-functional tasks – "Absolutely, well look at me, I'm a good example, I do everything from sales enquiries, I discuss the products and can talk about product aspects and attributes. And then also I dive in to the marketing, doing a bit of market research as well as developing or doing all the design, graphic design for the product as well. So I'm an example but there's, there's many of us that take on multiple roles, so yes we are [multi-functional]" (Participant C2).

During the interview the three participants were asked to rate the thoroughness levels to which they used their tools during the project on a 5-point Likert-type scale, where 1 = superficially and 5 = substantially. The following counts were obtained for each of the five ratings: 1:- 0 counts; 2:- 5 counts; 3:- 17 counts; 4:- 17 counts; 5:- 16 counts. The five tools that received 2-ratings (fairly superficial usage) were 'concept testing', 'brainstorming', 'change control system', 'limited roll-out' and 'customer satisfaction tracking'. When asked about customer satisfaction tracking, Participant 3's response was "it's done a little bit more on an ad hoc basis when we know that they [customers] have actually got something to say”. These results indicate that, generally speaking, in terms of thoroughness of use the three participants of Company C use tools moderately to substantially.

6.3.6 Tool Experiences

While some of the above examples show that tools are often modified to better meet specific requirements, there are also instances where applied tools have obvious shortcomings or where changing needs have outgrown a particular tool, but for practical reasons (e.g. cost and ease of implementation) no improvements have been introduced – “we’re using a software versioning tool to control those documents, which is far from ideal and it’s not the way it should, it’s not a particularly elegant solution there but having said that we haven’t made any changes to that yet. So, I guess that there are sort of tools that we’re not using for their purpose but we don’t always, yeah we’ve kind of lived with that I guess in some instances. We’d certainly like to change that particular tool out for something else yeah, something that is more kind of suited for that purpose” (Participant C3). “We have our own little supply chain management system which is on Excel which is not very successful, but we are still looking for an inventory management system” (Participant C1).

Other tools, such as ‘technology road maps’, have been identified as areas of weakness and some progress has been made to improve it, but not to a satisfactory level – “there is a roadmap of sorts but it is very conceptual, not clearly indicating how the product is going to develop over the next two to five years” (Participant C3), “we’re getting more detailed and more comprehensive in our road mapping” (Participant C2).

A couple of things are remarkable about this project. A first is the strong discipline and good practice of the team as a whole and of individual members despite it being a start-up company at the time. The NPD process that guides development efforts has been crafted very carefully and is constantly updated. All team members are familiar with it and keep to it as much as possible. Communication among the core team of 12 people was excellent throughout the project as is evident from the different forms in which meetings were and still are conducted.

A second aspect of this project is the excellent way that Company C collaborates with lead users, individual customers, consultants and suppliers. “We had Nurse Maude work with us to define the workflow of the user interface and also the format of the reporting”, “we contracted a consulting firm to review our user interface as just a normal user, not being a nurse, but just from a user interface side" (Participant C1); "we do have medical professionals working with us as they're the experts at the end of the day", "we also carried out joined research with multiple organisations, who are our customers, and published with them" (Participant C2).

Interestingly, though, despite the outstanding performance in the above factors, when asked to indicate a set of initial performance objectives, the project manager excluded both 'inter-functional cooperation' and 'external collaboration' from the list. At the time of the interview, though, the project manager did rate the actual performance in these areas as excellent (5 out of 5), but surprisingly gave low ratings to 'met product performance specifications' (3 out of 5), 'aesthetic design' (3 out of 5), 'ergonomic design' (3 out of 5), and 'customer acceptance' (3 out of 5). One way to interpret this is that the degree of inter-functional cooperation and external collaboration were not particularly important to the project manager at the start of the project because he knew afore hand that both would be done to high levels because of the way the process was designed and that the nature of the product would demand it anyway. What is less clear is why those average 3- ratings were given despite obvious good practice in most areas.

6.4 Company D

Company D began operations in 2002 by first developing a comprehensive business plan and a product design brief for a range of innovative home heating devices. The company spent the first three years working purely on their own designs, as well as undertaking some design contracting work for other manufacturers.

The initial research and development stage involved the use of an in-house design team as well as external design and engineering consultants. During the early stages of development of the product, which is the focus of this research, no NPD process existed. The project/product is categorised as more innovative, new-to-the-firm, and in some ways new-to-the world, but not radical or disruptive. It was only when a dedicated project manager was appointed that a formalised 5-stage process was introduced. Staff numbers grew from two to six full time employees during the first three years of business. The company launched its products New Zealand wide in 2005. Thanks to some exceptional leading-edge designs and some creative marketing flair, it is now selling niche heating devices throughout New Zealand, Australia and North America, becoming a market leader in just a few years. The business is thriving with an annual turnover in the bracket $6 - $10 million. In the past four years, the company has grown from 6 to 40 employees. The designations of the three participants are given below (initial interview times in brackets):

- Participant D1: Project Manager / Product Design Manager (13 July 2009 10am)
- Participant D2: Operations Manager (13 July 2009 12am)
- Participant D3: Chief Executive Officer / Market Research (13 July 2009 2pm)

6.4.1 Reasons for Tool Use

The formation of the core team that developed the product took more than a year to take shape, eventually consisting of members with plenty of NPD experience gained in best-practice companies like Fisher & Paykel, and others who never worked in design or production before. While the experienced team members constantly encouraged a formal approach to NPD and pro-active tool use, some inexperienced, younger members who played key roles in design tended to use tools much for its problem-solving attributes, often reactively - “they’d been quite a way into the project before they actually looked and found that they were actually heading down the wrong path”, often in hindsight applying the ‘ambulance at the bottom of the cliff’ principle: “Ok, we’ve had this stuff-up here, in hindsight what should we have done to avoid it happening?” (Participant D3). “Sometimes you don’t know you need a tool until a problem happens later in the product’s life cycle” (Participant D3). Participant D3 frequently uses the words “all of a sudden [they would revert to tools to overcome a problem]” to describe how things were done during the early days. This, and the fact that various functions often operated quite independently from another, frustrated the more experienced members who were pushing for more formalised structures and tool adoption that they were used to at companies that they worked for before.

As outlined in the company’s formal innovation strategy, the product’s competitive advantage was to be nested in aesthetics and functionality - “I can’t stress that enough, you know, the art side of what we do, the fashion, the furniture side is incredibly important, and we have to put in behind that well engineered, high-tech products” (Participant D3). Consequently, the use of design and market research tools dominated its development - “we placed a great deal of emphasis on product design, the aesthetics and functionality of the product” (Participant D2). Not surprisingly, in the online survey the project manager rated the company’s performance in aesthetic and ergonomic design 5 out of 5 (excellent). An experienced project manager joined the project about a year after its start, and quickly introduced a more formalised approach to the way the rest of the team was operating until then by introducing project management and a five-stage NPD process. Still, for most of the project, the emphasis was very much on state-of-the-product matters, supported by in-depth market research to help define the product specifications - “there are tools out there which we currently don’t use and maybe should be using” (Participant D2). While some tools are enforced by normal company procedures independent of the NPD process (e.g. ‘computer-aided design’, ‘engineering document management system’), most tools are not - “but it happens anyway as a matter of course” (Participant D2). Team members are constantly encouraged to adopt and use tools to make the whole process, including decision-making, “more visible, and more recorded” (Participant D2).

From his past NPD experience, Participant D3 expresses his concern that often companies spend plenty of time up front developing a product brief, just to lose the plot post-brief with poor process. “And that’s where I think most of the key product development tools that I’m aware of have a part in absolutely making sure the end product actually resembles the brief. And far too often it doesn’t.”

Right from the start Company D had a strong focus on export markets (in addition to the local market), and this focus made them realise they needed more formalised systems and tools had they simply targeted the local market - “... we need three times the horsepower to develop them [products for export]” (Participant D1). The more complex distribution channels associated with export also created the need for tools to “build products smarter” to ensure sustainable and profitable margins throughout the product life cycle (Participant D3). The development team placed very much importance on the initial product brief (target specifications), and used tools to a large degree to ensure the end product actually resembles the brief - “that’s where I think tools have a place, trying to make the process disciplined enough [to ensure the final product meets specifications]” (Participant D1).

6.4.2 Tool Adoption Process

For most of its development time, the project under consideration had no formal NPD process to guide its progression, and once a process was introduced towards the midddle of the project, it did not really play a significant role. As such, tools were not linked to the process: “it was kind of pretty loose at the time”, “people were kind of aware what should happen and when it should be happening” (Participant D1), “so we kind of made it up as we went along” (Participant D3). Often tools were put in place reactively after mistakes had been made “and then put the tool in place” (Participant D3). The MD realised the importance of bringing in people from the outside that had plenty of NPD experience, "maybe 25% [of what we currently have] were things that Employee X brought to the table from his past, good tools that are now part of the process" (Participant D3). Participant D2 sees the adoption process closely linked to a learning curve effect where over time new people make others aware of tools, bringing in new tools earlier in the process (e.g. pre-testing and evaluation), and even making improvements to the process itself. Not only were new tools adopted into the firm over time, but existing tools were used more thoroughly and formally as progression was made down the learning curve, e.g. the use of 'time studies' (Participant D2). An evolutionary process started with the first project and continued with subsequent projects: "I think it is fair to say in the latter part of that project, yes there was more structure, there were more things that had to get done before, you know, step one needs to be done before you get to step two. And we're starting to do that a lot better on all of our new projects" (Participant D3).

Specific triggers for tool adoption included training courses offered by the Otago Chamber of Commerce on 'lean manufacturing' which apparently was partly funded by the New Zealand government, and the fact that Company D had to comply to external governing bodies' tight regulatory regimes (export requirements) (Participant D2).

6.4.3 Obstacles to Tool Adoption

In the online survey, Participant D1 pointed out 'insufficient budget', 'requires too much training', and 'lack of time' as potential barriers that may have prevented Company D from adopting more NPD tools in developing the product. Apart from these, Participant D3 attributes low tool adoption at the time partly to "doing low budget, unstructured development". This cost them dearly as they "essentially had to design the product twice", "for the purposes of getting the cost of manufacturing right" (Participant D3). Thus apparent cost savings and shortcuts taken during the early stages of the project soon came back to haunt the team later in the same project. Other obstacles include tools' questionable return on investment, the fact that tools often require intense training, and coupled to that, a general lack of time (Participant D1). "I think one of the problems in general is to try and I guess educate people to the benefits of the tool that's in question. And sometimes it's quite difficult if people are set in their ways as it were to try and put some change on them and say, 'Well maybe we shouldn't be doing it like this anymore, maybe we should do it some other way and maybe we should use this tool to help us reach our goals'. So I guess it's just adversity, the change is a big obstacle" (Participant D1).

Participant D2 cites the lack of 'exposure avenues' as another potential obstacle to tool adoption: "When I came here the people didn't have any avenue to get exposed to all that [tools], so they didn't know these tools ['Kanban', 'design of experiment', 'Kaizen', 'the Toyota way'] existed. And I suppose that once you start getting exposed to some of these tools you realise that there are a lot of tools out there and then I suppose you potentially, if you don't have the right one then you go looking, whereas if you haven't been exposed to those tools then I suppose it's almost like, I suppose the more you know the more you realise that, the little you do know".

6.4.4 Tool Familiarity

During the interview the three participants were asked to rate their familiarity with the tools they used during the project on a 5-point Likert-type scale, where 1 = very little and 5 = very much. The following are the combined rating counts: 1:- 1 count (collaborative product development); 2:- 5 counts ('in-market testing', 'computer-aided manufacturing', 'customer satisfaction tracking', 'change control system'); 3:- 19 counts; 4:- 34 counts; 5:- 23 counts. This indicates that generally speaking, the five participants of Company D mostly display high levels of tool familiarity with the tools they use, but at least five tools that have very low familiarity levels (1 and 2 ratings), may deserve more attention.

Apart from the three more experienced participants, it appears many of the remaining team members, during those early days, were very young and inexperienced: "When I started, certainly, you know, they wouldn't be familiar with these tools", "design for assembly was like a foreign word to them", "it's just that not many had been exposed to those type of tools. But yeah, you need exposure over the whole company, we need to create our own culture I suppose, we need to get that team feeling that people on the floor can make a difference and can have input into their area" (Participant D2).

6.4.5 Tool Usage

As previously stated, an NPD process (a tool in its own right) was introduced towards the middle of the project under review and as such it did not have much influence on the way this particular project was executed, understandably so. Yet, at the time of writing this report, when several subsequent projects have been undertaken, it appears from team members' responses that the formal chartered process has not really been implemented or promoted among team members - “is it like a flow chart?”, “yeh, I remember seeing something but I have not compared it to what they actually did” (Participant D2), “probably not very well [followed]” (Participant D1). Prior to having the process introduced, the team devised a fourty-step plan (checklist) on how to introduce a new product, which is still in circulation, but that, too, failed to be implemented to a satisfactory degree - “Design (consisting of four to five people) haven’t been able to get past about step twenty, they have never actually with the last three products they have introduced - they’ve never actually got any products signed off” following a systematic sequence of activities (Participant D2). Consequently, just prior to production special meetings had to be organised to get everyone back round the table to formalise production sign-off (obtain final approval). This does not mean that Company D operates completely without an NPD process, far from it – indications are that they do work according to some overall guiding structure, but it possibly lacks transparency among all team members, and formalisation. This is evident from Participant D3 when acknowledging that they have definitely made improvements to their process over time: “at the beginning of the project our own new product development process, overall meaning the accumulation of tools that we used, was somewhat loose and floppy. And I think as we’ve gone through we’ve firmed that up. But one of the key ones we’ve learnt is around at what stage do you involve an outside testing laboratory? … What we’ve now learned is to put a step in there [in the process]. We call it pre-test evaluation where we send an alpha or a beta prototype, quite an early model, to the laboratory and we say, ‘Don’t put this through your approval process, but look at it and tell us where you think it may fail and do those tests on it and tell us have we failed and if so by how much?’” Participant D1 proposes how the process can be improved: “I feel the whole process needs to be more considered and more open, so I’m hoping that using and adopting some of the tools in the online survey will help everyone make the whole process more visible as it were and the decision-making process more visible and more recorded. And hopefully everyone will then try and understand that yes we are going in the right direction”.

Overall, Participant D2 rates company D’s approach to using tools and following process much less formalised than, for example, a larger company like Fisher & Paykel. Participant D1 agrees: “[Tool use] is pretty informal presently, but we see a time in the not too distant future where we make them more formalised”. As a result, Participant D2 identifies a number of potential negative consequences for the firm. “I think as soon as you lose your structure and lose people following processes then you open yourself up to a whole can of worms, potential warranty issues and stuff." Especially for a small company that does not have many resources, if someone rushes through a change without following due process it has the potential to "create a lot of mayhem out there". For example, if Design introduces a new type of assembly or make a modification of some sort but fails to inform other functions, it may negatively impact them. Insufficient structure furthermore does not necessarily record good practice for future reference, which means that teams in subsequent projects may have to go back to first principles every time they encounter a situation that may have been successfully addressed during a previous project. Thus, teams don't progress down learning curves as fast as they could. Participant D3 echo's similar sentiments - "[with the current project] we got there in the end but not necessarily by use of a great number of tools". Consequently, prior to launching the product in Australia it needed a few "fix ups" and even at the post-release stage, several re-visits were required that involved design changes to improve the cost of manufacturing.

Participant D3, who was heavily involved in scoping out the new product brief and subsequent ones, describes his style as follows: "I don't really use formal tools for doing that [scoping the product brief]. I mean I make notes all the time, I store specific emails in a specific place so I can go look back on them, that are ones relating to new product development. And I put thousands of hours of thought into it. And then I look at other factors like what's happening with energy use, what's happening with size of houses, size of rooms, what I think the regulators are gonna do, I look at an enormous number of factors and if they all fit together then I might put forward a proposition to say we should look at developing a [heating device] that's twelve foot wide. But I'm not convinced I could really claim to follow any specific process to do what I do, it's more done on just what conversations I manage to pull together in my head and intuitively know is the right way to move forward." Clearly, Participant D3 does not necessarily rely on one specific tool with a specific name to carry out his activities, to get him the results he need. Instead, he uses aspects of a variety of tools of which the names don't matter, until he feels confident that he can draw a sensible conclusion and make a calculated decision.

During the project under consideration as many as 33 tools (out of a possible 76 on the list) were implicated in the development project at some stage, if only aspects of a tool. Brainstorming, for example, was ticked off on the list, but team members were never consciously aware that they were using this particular tool - "we have meetings with lots of people and a whiteboard, so we don't call it brainstorming, but that's really what it is"

(Participant D3). (It is debatable whether the brainstorming tool has indeed been used in this example. Using the tool dimensions and characteristics developed in Section 2.2.3 (p. 15), I would argue that the brainstorming tool had indeed been used, as the degree of formalisation is vague - the user was able to identify it in hindsight - and its scope moderate - it clearly had some structure.) The same holds true for most other tools - “you do some of those things automatically” - without necessarily naming tools while using it or implementing them according to the letter of the rule. The reason given by Participant D3 for this, citing the example of focus groups and its inherent limitations, is “they’re certainly not a gospel”, “... I’d hate companies to think that there was some guaranteed process they could follow which would guarantee the success of a product. It simply does not exist, otherwise we’d all be rich”.

Which raises the question: how strictly do people follow the ‘user instructions’ for a particular tool? A word mentioned several times by participants in this context was ‘intuitively’. “I probably use tools more intuitively” (Participant D2), “...I manage to pull things together in my head and intuitively know what is the right way to move forward” (Participant D3). However, there are exceptions - for example, “the tools I use infrequently I probably would more stick to the rules... just to make sure you are doing it right” (Participant D2), “... certainly things like ‘engineering document management system’, ‘change note control’, and ‘failure modes and effects analysis’, all that type of stuff needs to rigidly stick to the form that we’ve decided. So they are pretty much policed and enforced with regards to how they are [implemented]” (Participant D1).

While project team members may not always see the need in following user instructions of individual tools more closely in practice, they do see the value of ongoing improvement in how they are following processes and applying tools - “... there is endless, infinite opportunity for incremental improvement, but only if you constantly look for it and then ratchet your systems and processes up accordingly” (Participant D3).

Two concepts that go hand-in-hand with the tendency not to strictly follow tool guidelines, is flexibility of use and tool modification. Both these are in the order of the day at Company D: “I use tools quite flexibly” (Participant D2), explaining how a Kanban system was re-interpreted to better suit the company’s requirements, and “Yeah that tool’s pretty good but we’d like to just tweak this and that and the other” (Participant D1), citing ‘design change management’ and ‘failure mode effects analysis’ as examples. The informal NPD process, as a tool, is no exception. Participant D3 explains how they modified the regulatory approval part of their process by instigating a pre-test evaluation step where an early prototype is sent to England for early feedback purposes so they can affect changes early in the design stage and thus potentially avoid costly corrections at the time of the formal approval process.

During the interview the three participants were asked to rate the thoroughness levels to which they used their tools during the project on a 5-point Likert-type scale, where 1 = superficially and 5 = substantially. The following counts were obtained for each of the five ratings: 1:- 8 counts; 2:- 23 counts; 3:- 9 counts; 4:- 18 counts; 5:- 14 counts. Eighteen tools received 2-ratings and below (indicating superficial usage), which is of potential concern. They were 'collaborative product development', 'scenario planning', 'engineering document management system', 'knowledge management', 'checklists', 'computer-aided design', 'design of experiment', 'rapid prototyping', 'computer-aided manufacturing', 'focus groups', 'brainstorming', 'stage gates', 'design mock-up', 'intellectual property protection', and 'limited roll-out'. These results indicate overall quite a high count of instances where tools were not used substantially (ratings of 3 and below).

When asked why some tools were more thoroughly used than others, Participant D1 suggested it was because they place more value on the former as they anticipate more benefits from those tools. Participant D2 provides a different insight into this, using 'time studies' and 'material flow' as examples. While these particular tools have many dimensions of complexity in terms of their use, the people using these tools only use it at a basic level as they were not "at that stage yet [where these tools can be used more thoroughly]" and besides, at the current levels of usage they were already reaping considerable rewards with which they were very satisfied with - "like the gains we are after are quite obvious, you know, it's like you take the big ones that are falling at you". The MD provides another plausible answer to the thoroughness question, linking it to the evolutionary stage of the firm - during those early days "we hadn't really been exposed to formal development tools. So, we kind of made it up as we went along. Some tools are also more relevant to us than others". As more experienced people joined the team, team members were not only introduced to more tools, but were also taught how to better use tools and were exposed to some 'world best practice'. This is seen as an ongoing process, where over time team members are likely to increasingly use tools in a more thorough manner than they did in the past - "we're starting to do that a lot better on all of our new projects" (Participant D3).

Participant D1 contributes part of the product's success to the attention to detail that they paid to aesthetic product design early on in the process – "rather than just saying, 'that'll do', and then move on." Feeding in to this is the company's strong reliance on trained industrial designers, and of course, the great job they do in researching the market prior to finalising the design brief. Some tools were specifically mentioned: 'Design for excellence', 'focus groups', 'design mock up', and 'design reviews'.

6.4.6 Tool Experiences

The NPD process that was eventually put in place never functioned well during the development of the first production units. Even though the development team was relatively small, surprisingly development activities often took place in isolation, and were characterised by poor communication - "in a company this size the communication lines aren't necessarily that good" (Participant D3). Participant D1 agrees with this in rating communication among departments at 2 out of a possible 5. Although individual members seemed to be specialists in their fields, they would "lack the complete picture of how to introduce a product", some appearing to have never taken real ownership of the project - "they weren't grabbing the product and making it their own" (Participant D3). As part of a survey questionnaire, Participant D1 gave ratings of only 3 out of 5 to both 'degree of inter-functional cooperation', and 'degree of external collaboration'. Participant D3 puts a lot of these poor performance down to the fact that their relatively small team was working out of multiple offices in different buildings. "Which means people work in isolation and we don't have good meeting rooms and things. I believe our current site which we are about to move from in four months' time to a purpose built one, I believe we'll have a massive improvement in the interaction between the people that do our product development when we put everyone in the same room and give them big meeting rooms and the appropriate spaces to actually carry out some of those soft interactions. But yeah right now I'm, I mean I do my best. I hold staff meetings and tell them what's going on right throughout the whole company. And we do our best to communicate between us, but no I believe we could improve that side of things."

From the participants' descriptions it seems that the company is very much run by different functions, which include, amongst possible others, Design, Procurement, Operations (Production & Assembly), Finance and Marketing. The same applies to the way NPD projects are run – individuals form teams that belong to specific areas and when they have their two weekly review meetings, each team clearly represents a particular area. These meetings "were all run by Production and like all the minutes were taken by Production and because Design wasn't taking ownership" (Participant D2). 'Ownership' was claimed by and belonged to one group, Production, and this made it difficult for other groups to really feel part of the project. In the online survey on tool application and use that preceded the interviews, the project leader indicated no use of cross functional teams, which could potentially be a useful tool for solving the ownership issue. The low rating of 3 out of 5 given to the degree of inter-functional cooperation is a further indication that the functional team approach to NPD may not be the best option for Company D.

While the training aspect of tools has been implicated as a potential barrier to tool adoption (Participant D1) – in terms of setting aside time for training, the company has realised the importance of providing training to staff in specific areas, such as 'lean manufacturing' – "there was a number of us that went on a course early on this year and we're gonna push 'lean manufacturing' through the factory and obviously that's got a flow on to Design as well. Design really has to go do the 'design for assembly' and everything else" (Participant D2). He continues to describe the challenges of converting product designers and factory workers who predominantly have a job shop background, to an assembly line environment – "When I started, our assembly line was more like a workshop where people were just assembling product rather than a factory assembly line. It's just that the people had never been exposed to an assembly line before so they didn't know, they thought that they were doing okay", "I've given them a 'design for assembly' book, so they can have a look at it", "and there's people out there who have got that, I call it the batch mentality, you know, they like making a batch of something. And you try and say to them, 'Well a batch is no good because all it does is put a strain on things further down the line.' I said, 'well I want three a day of that, I don't just want nothing for a week and a half and then twenty of them,' I said, 'that's no good to me as it just chokes up the system further down,' you know? And it's just convincing the people", "trying to push the lean approach I suppose. And all those tools that come with it ask, 'Why?' When I first started here they didn't know that you asked 'Why?' so many times and you felt like they wanted to hit you after about the third time."

While Participant D2 acknowledges the value of tools and appropriate training, he is cautious of using tools to overanalyse situations "if you come across a problem you can, people have dealt with something similar before they'll have a solution which seems fine and because it's a known solution, yeah you don't necessarily need to go back to the first principles of having a brain storming session. And I think you can just proceed with implementing the solution really. But yeah, you don't need to overanalyse everything before you go for implementing a solution really." He also stresses the need for good communication between departments to avoid situations that he observed "when they introduce a solution and it creates, introduces a problem somewhere else, so you haven't solved a problem, you've just moved it from one area to another".

Discussing the use of 'focus groups', Participant D3 questions the value of some NPD tools in specific situations. "From a marketing point of view you can sit down with a focus group and they will tell you all, whatever they want to about a [heating device] based on the [heating devices] they've seen before. So when you show them five [heating devices] and say, 'Which one do you like best?' they'll make their decision based on the [heating device] they saw in their Mum's house or in their neighbour's house and of course those fires were designed five, ten, twenty years ago. So focus groups can only tell you about the past they can't tell you about the future. So when you sit down to design a product you have to be basically saying, 'What are people gonna be buying five, ten years from now?' Not, 'What are they buying right now?' And I'm not convinced there's any great tools for doing that apart from basically a bit of intuition and spending a heap of time face-to-face with your clients".

Having previously worked for a large NPD firm in New Zealand, Participant D2 points out the small-company problem where product designers, although they are often forced to wear many different design hats, don't get the opportunity to become well rounded product designers. It is standard practice for larger companies to engage designers in every aspect of design, including concept, prototyping, pilot and production where they receive specific training and guidance from other experts. Consequently designers become familiar with all the steps in the NPD process, whereas at smaller companies designers "don't necessarily get that whole idea of how to introduce a new product", which has the potential to cause problems. He cites as an example a project (not the one under consideration) where Product Design called a meeting after a product went into production and requested/introduced plenty more requirements, without informing other departments such as Production and Assembly. This sort of action is indicative of people not understanding the NPD process, not keeping to protocols that have been put in place to ensure activities are done systematically.

In hindsight, the project manager thinks a number of aspects worked very well during the project: design for own manufacturing constraints and processes, aesthetic design, and flexibility of installation. On the other hand, the approval process through test labs was more difficult and protracted than anticipated.

6.5 COMPANY E

Company E is a global leader in designing and delivering radio communications devices aimed at a variety of niche industries. It was incorporated in 1962 and has a staff close to 1,000. While several corporate functions are based in Christchurch, the company has an international customer base and runs a global support network. It works with a network of sales/support offices, dealers, system integrators and consultants that spans the globe.

As Company E has been in the NPD business for several decades, they have well-defined systems and processes in place with highly trained practitioners that aspire towards 'best practice'. All NPD projects are guided through a sophisticated seven-stage NPD process (they refer to it as a new product introduction (NPI) process as it includes aspects of market introduction), with distinct in-between gates where cross-functional teams make important decisions. Despite the company not having a formal corporate innovation strategy to guide its many development projects, in many ways, they can be seen as a role model for product development in the New Zealand context. The product under consideration in this study is a product repositioning with several new-to-the-firm innovative features and technologies introduced in this release. The designations of the five participants are given below (initial interview times in brackets):

- Participant E1: Project Manager (26 May 2009 4pm)
- Participant E2: Hardware Project Manager (2 June 2009 2:30pm)
- Participant E3: Mechanical Design Engineer (5 June 2009 3:15pm)
- Participant E4: Software Project Leader (9 June 2009 2pm)
- Participant E5: Product Manager (17 June 2009 11:30am)

6.5.1 Reasons for Tool Use

As Company E is a mature company with years of experience in product development, they have an established NPD process in place. In some ways the process is quite prescriptive in which activities need to be carried out – "we referred to the D gates all the time, we used them all the time as our gospel, as our goals", "we also used the Intranet, we had an Intranet page for the development. So you could go straight onto there, look at the latest actions from the core team, look at the timelines, look at where we were at in this stage gate process" (Participant E5). While in other areas "it's fairly intuitive what needs to be done at each stage" (Participant E4). The process furthermore dictates or requires the use of certain tools (such as 'business case', 'ROI analysis', 'design reviews and approvals', 'voice-of-the-customer') at certain stages in the process - "some tools are extensively used because we know they work and they are part of our stage-gate process", "but only a few critical tools are mandatory, for example the 'issue management system (TIMS)', 'stage gates' and 'project management'" (Participant E1). In other instances the process may suggest or direct users to certain tools, but leave it to the user's discretion which tool to use – "well, to do risk management, you may consider …" (Participant E1). Participant E5 describes how he used 'checklists' for each phase as a reminder of what activities needed to be carried out, for example "say the D1 phase, you've got to make sure the business case actually stacks up, whereas at D3 it's down to more detailed stuff like making sure all the product's codings are on our system, and all the pricing's in place". Not all tools are linked to the process (e.g. Microsoft Project), however: "I sort of knew I had to use those tools ..., ... as there is pressure from the group, the core team" (Participant E5).

Because the company has invested millions of dollars over many years in hardware, software, and the training of people, everybody is part of a culture characterised by orderliness, structure, and cooperation - "well, this is how we do things"; "this is just culture and we know it works" (Participant E1). Hence, while practitioners in Company E may use some tools because the system demands it from them, it does not mean that they feel they are forced to use such tools or that they are sometimes reluctant to do so. To the contrary, they respect the system and acknowledge its necessity "we need tools to get the same sort of consistent outputs that we require to keep us all on track" (Participant E5); "by having a standard set of tools, people are speaking a common language" (Participant E4).

Some tools, such as 'CAD', are not linked to any process or enforced by anybody, yet are widely used because they are so deeply integrated into the activities that they cannot be separated from it (Participant E1). Some niche tools are very much linked to individuals – "if you want to be engaged or get some output in 'competitive benchmarking' or 'portfolio management', then you go and see [a specific company individual who is regarded as the local expert]" (Participant E1). Other tools such as 'development and debugging' tools in software design and 'finite element analysis' in mechanical design are linked to specific functional areas

- “floating around the place” (Participant E3) - but even such tools are mostly referenced in the company’s management system. “Significantly more than 50% of these [tools] are referenced in our quality system” (Participant E1).

Similar to the other case study companies studied here, Company E also uses tools for effectiveness and efficiency reasons, but seems to stand out from the rest with regard to their expectations that they also use tools with a longer time frame in mind than just achieving an immediate outcome, both with regards to product and process. In terms of product: “You know it is going to be a good product and a reliable product and able to be manufactured and meet the customer’s requirements, keep the customer happy” (Participant E2). Tools are not only used with an immediate outcome in mind (e.g. to solve an immediate problem e.g. ‘mind mapping’, ‘brainstorming’, ‘failure mode and effects analysis’, ‘design for X’, or get the product to launch stage), but with a longer-term view where future benefits are anticipated - “to analyse what we are doing, to increase our understanding” (Participant E2). Often, new tools were sought pro-actively with the expectation, based on experience with other tools, that they will add value (Participant E1). In terms of process: “We have evolved a system including tools into something now that we have a reasonable good understanding of how it works for us. If there are future issues, like if we have an injection moulding tool that gets damaged and we need to re-build part of it, you know that the people looking after that product can re-build it, and have the information necessary to re-build it. Or, we might have a supplier that’s maybe gone out of business or having irresolvable issues requiring someone else to make those parts. We pick up our manufacturing tool(s) e.g. injection mould and take it somewhere else and those people need to know what it is that we want them to produce. These are examples where our documentation and all of our procedures around that are very important” (Participant E2).

Other reasons cited for using tools stem from the relatively large size of this particular development team (35 in the core team and 90 in total) and the very collaborative nature of this project, among many individuals “I had to use those tools as there was pressure from the group”; “we were collaborating all the time with different groups, we needed to use tools to keep everyone on the same page” (Participant E5); “tools provide information in a format which is available and meaningful to a lot of other interested parties ...” (Participant E4). Apart from using ‘stage gates’ for its obvious purposes, it has an added benefit as “it sort of forces the organisation to be engaged” (Participant E1).

6.5.2 Tool Adoption Process

At the time when the project under consideration ran, most of the tools used during the project were already internalised within the company. Only about 5% to 10% of tools used during the project were newly adopted ones because of situations “where we suddenly realised we haven’t got any tools for a particular problem” (Participant E4). Two out of the five participants said they were pro-actively looking for new tools during the project. So-called technology leaders are responsible for introducing new technologies into the company in a responsible way to avoid any instances of incompatible tools and tool duplication (Participant E3). They also control the issuing of tool licenses (e.g. for licensed software) and manage requests for new tool purchases. Most standard software tools are made available to users via the company Intranet or internal servers, apart from the tools that individuals develop themselves (Participant E5).

For relatively small and inexpensive tools, individuals would simply make the purchase paying for the tools themselves, then simply get refunded at a later stage (Participant E1). Once a user has trialed and tested a particular tool and found it to be useful in a particular context, it may eventually become part of the firm’s routines “this is the [Company E] way of doing it” (Participant E1). For larger tools that require a significant financial investment, users must prepare a business case and follow a formal process of assessment and decision making before such a tool can be purchased and internalised (Participant E1). Although it can be quite a challenge to succeed with such applications, it usually is not a big problem. At the time of writing this document an ‘EDMS’ system was being trialled before the decision is made to roll it out for standard use among all future projects. Smaller tools that were only recently adopted in an attempt to improve the fuzzy front-end (FFE) of the process include ‘competitive benchmarking’, ‘life cycle analysis’, and ‘business case’ (Participant E5).

Participant E5 observes a trend where tools, in general, are becoming more sophisticated, and practitioners opting to adopt more commercial tools built for purpose (often replacing their custom-made tools e.g. replacing ‘requirements analysis’ and ‘roadmapping’ spreadsheet-based tools with licensed tools), rather than designing their own. A specific case in time is the company’s use of ‘voice-of-the-customer’. While the company was developing the product, it did not have a formal system for capturing end-user requirements - “We go out and visit customers...”, “I think we took what we could get, at the time. And there probably were a lot of things we could’ve got if we’d used the tool to its maximum”. Whereas today, “we’ve got a full ‘voice-of-the-customer’ programme in place now, where we’ve all had the ‘voice-of-the-customer’ training, we’ve got a formal method of capturing the information and so that’s really good from a requirements capture point of view”, “if I look at the original ‘product road map’, it’s quite sparse, but now it’s actually quite in-depth as far as how we present it” (Participant E5). Another example of a tool evolving over time is given by Participant E2: “We did not have an official ‘EDMS’ system, we do our own version of it and I guess we have been refining that each time we do a new project. In the past it’s been terrible but we have improved it to a point where it’s easy to follow.” (Note: At the time of writing this document Company E was considering purchasing an official ‘EDMS’ for use by the entire company.) Some see an immediate need for further tool evolution in specific areas – “we know what our portfolio is today, we know where we’d like it to be tomorrow. But to manage that and keep it all in check we needed more sophisticated tools than just separate spreadsheets running on people’s laptops, all over the place” (Participant E5).

However, the opposite is also true where custom designed tools replace commercial ones because of its inflexibility of use – “in one project [not the one under consideration] we tried to use a formal ‘CAD’ data management tool. We found it to be such a hamstring on what we were doing that we abandoned it in the middle of the development which was a pretty big thing. From that point we went back and further developed our own system. It’s not ideal, but it works for us” (Participant E2).

Often when new and more comprehensive tools are brought into the company, teams from the main functional areas or disciplines, such as marketing, would invite project teams to attend presentations where they would show them the capabilities of these tools, enquire about specific user requirements, and even provide training on how to use such tools. A training department at Company E furthermore provides training on any software or tools in use where staff can book for training on anything they require (Participant E5). A good example was when the company rolled out its ‘issue management system (TIMS)’ – “so everybody in NPD areas, not just development, overall had four months of extensive training (individuals received two hours of training). We had a group of about a dozen people who would then go around everybody, about three hundred people or so, and spend at least an hour with them, on their PC, setting it up, showing them, and then letting them walk through it, letting them raise an issue, progress it through all the different stages, close it again, and provide reports and, so that was done very formally” (Participant E1). Three of the five participants indicated that they received formal training at one stage or another in one or more tools at the company, while all mentioned that they normally do their own learning as well and that they also rely on what they learned at university.

In addition, individual groups arrange their own means for keeping in touch with the latest technologies. The software group, for example, has fortnightly technology meetings where technology leaders, vendors, and individuals get the opportunity to recommend tools or discuss problems and/or requirements. This particular group also uses an online forum to discuss these issues (Participant E4).

The project manager's views on tool selection is typical of how projects are executed at Company E. "I'm basically given a job to do and really what we want to use from all of this and potentially more tools and processes is, with a few exceptions, a few of the mandatory ones, is very much up to me and my core team, we can decide, it's up to us. We need to get a job done and how we want to do it, and whether we use hammers or nail guns, or whatever, that's largely up to us."

6.5.3 Obstacles to Tool Adoption

In the online survey Participant E1 pointed out 'lack of awareness (did not know more tools were available)', and 'the value of the tools is unclear or not well enough explained' as potential barriers that may have prevented Company E from adopting more NPD tools in developing the product. Not that Company E has only used a few tools, to the contrary, they indicated 52 out of a possible 76 in the survey. Apart from these, Participant E1 also observes that for the more expensive, elaborate tools not only the direct financial cost is a factor to consider, but also the amount of work that may be required to do proper due diligence on a proposed tool, to prepare the necessary documentation, implement the tool, provide training, and keep reinforcing it among project teams. "That is a huge undertake" (Participant E1), and may be considered an obstacle to the adoption of a particular tool if it is perceived that the opportunity cost is just too big for the potential return on investment. "We could use these people [project team members] to implement the new tool, but we could also use these people to create new products too. And generally, it's easier to demonstrate return, value from working in the business than it is working on the business" (Participant E1).

Participant E1 mentions a typical comment he has heard on occasion from people involved in the project "... for many years we were quite successful without doing any of that, so, why do we do this?” This type of attitude can be an obstacle to tool adoption and be quite difficult to overcome. In more specific terms, engineers have been found to be very biased against team building tools - “they just think it is a waste of time, they tend to view it as ‘treehugging’ and then later complain about some team members not cooperating, or having difficulty working together with certain individuals”. Some tools are also perceived to have too long learning curves that must be traversed before worthwhile benefits emerge, which make them unattractive (Participant E3). An example of such a tool is the TIMS software tool (an issue management system), which according to Participant E5 was not intuitive to use and perceived to require too much training. In the end pragmatism dictates which tools are adopted - “you have to choose the shortcuts that are the least pain” (Participant E1). An example of this was carrying out a post-project review of this particular project, which is something the project manager had all the intentions in the world to do. However, because of severe time constraints he never got around using this tool - “I just simply didn’t have the bandwidth to do it. I promised the team members that I would collate the data, but I failed to do it.” The reason for this was that other, higher priority tasks prevented the use of this ‘mission non-critical’ tool, and it was left for another day - “a next step in our maturity of running projects like that” (Participant E1).

6.5.4 Tool Familiarity

During the interview the five participants were asked to rate their familiarity with the tools they used during the project on a 5-point Likert-type scale, where 1 = very little and 5 = very much. The following are the combined rating counts: 1:- 2 counts (lead user, concept test); 2:- 13 counts (‘design of experiment’, ‘alpha prototype’, ‘value added/value engineering’, ‘competitor analysis’, ‘roadmapping’, ‘engineering document management system’, ‘voice-of-the-customer’, ‘marketing plan’, ‘team building’, ‘post project review’, ‘change control system’, ‘bug tracking’’); 3:- 28 counts; 4:- 55 counts; 5:- 18 counts. This indicates that generally speaking, the five participants of Company E mostly display high levels of tool familiarity with the tools they use, but at least the 15 tools that practitioners have very low familiarity levels (1 and 2 ratings) with, deserve some attention. ‘Voice-of-the-customer’, for example, received little attention at the time of the project as the so-called Fuzzy Front End of the NPD process was not well developed – “…because we never really used it for this project. But now, we’re starting to use it a lot more in this next project” (Participant E5).

6.5.5 Tool Usage

Approximately ten years ago, Company E developed and put in place a 7-stage new product introduction process that they have been using ever since as a generic tool to guide the development of new products, from incremental to more innovative ones. However, the process has not had a significant review or modification since the original structure was put in place - "so there's very little time, particularly in the last ten years or so..., and that's partly why the whole NPI process is pretty much the same as it was ten years ago. There are a few odd exceptions where we've made improvements" (Participant E1). One significant change that was made to the process, but not documented, was to make the stages more concurrent. For example, the NPI process currently specifies when the manufacturing and sales functions should become involved in the process, which the project team decided was too late for their liking - "so we had manufacturing involved earlier, we got the sales divisions involved early. Historically we would release a product and our main sales divisions would then say, Okay, we will now get our people trained, we will look at planning a launch to our customers. So that'd be after the product's actually available. And this time [with the project under review] we had them available beforehand, so when we got to the initial launch of the product they'd already done all the training, they had technicians who would be supporting, had been trained and they were ready to actually do a launch" (Participant E3). By involving various parties at an earlier stage than what the process would necessarily prescribe, it gave everybody a chance to better prepare for their deliverables and address potential issues ahead of time, which eventually sped up the whole process (Participant E4).

The biggest reason why the process has not afterwards been updated, appears to be time constraints: "We have every intention, when we change something, when we find a better way of doing something, to actually then go back, at some stage, update our systems, and whatever. But that moment never comes. Because as soon as we got sort of close to the end of the project there is so much pressure on all of us, we're already running late on the next big thing, so there's so much pressure to drop, finish this as soon as you possibly can get back on to the next" (Participant E1).

In terms of flexibility of use, Company E followed two main approaches. Some tools, such as stage gates, TIMS, check lists and project management, were used in a way that can be described as "fairly focused, fairly sort of, what's the word, prescriptive of what we need to do", “there are fairly strict sort of ways of how we record, report, resolve, close issues and bugs and problems and all that, with risks, that’s fairly prescribed. So with those ones we have very little, definitely little flexibility” (Participant E1). With a second category of tools, though, the project manager and his team had much more flexibility in how they could apply the tools, tools such as ‘value added engineering’ and ‘intellectual property management’, even though there were guidelines for using these tools - “yes most of the things we do we are customising the way that we do it to get it to best suit our needs and get the best result in the shortest time possible. You know we obviously don’t want to set up a huge experiment that’s going to take four months to produce a result when we need an answer in a week, we just can’t do it” (Participant E2). “And I realised that sometimes, ..., if you actually used the tool more thoroughly we would get more value. It’s a matter of being pragmatic in using tools to a level that they provide value” (Participant E1). “I guess from a theoretical point of view, it’s always best to get the maximum out of the tool that you’re using. But I think sometimes there are constraints and answers that are needed sooner rather than later, so sometimes there could be some shortcuts taken on tools that you use” (Participant E4). Examples include ‘project management’, ‘planning and scheduling’, ‘computer aided engineering’, ‘modeling and theoretical analysis’. “We do enough to get some level of confidence, then implement” (Participant E1). “I mean I think that’s purely a resource thing. Because we just don’t always have the time and resource to do it properly” (Participant E5). “There’s usually a lot of pressure on us during product development to achieve as much as we can in a very short space of time, so you’ve got to look at ways to most efficiently use that time and get an answer as rapidly as possible” (Participant E2). “There’s a whole range of tools that we can use. I think it is a case of choosing the appropriate tool at the appropriate time” (Participant E4).

Participant E1 explains how they were able to discuss how exactly they were going to manage the product’s intellectual property rights - “Well, we could do all of these, looking at protection of all sorts of aspects of our product but we decided, well, no, we’re not gonna do it, we’d rather actually met other criteria of the project, like being on time and delivering to scope, than putting all the effort into protecting some intellectual property”. From this, it is clear that sometimes a trade-off is necessary between thoroughness of use - “so it’s always a fine line between, well how thorough, how flexible, how much you follow prescription” - and other project objectives - “because you can’t do everything on everything, because you’ll be still here developing something in twenty years time, and the market doesn’t use these products anymore”.

Flexibility of use may sometimes lead to conflict among team members, as the IP example further demonstrates of what happened at a stage gate meeting:- Intellectual Property Manager: "Oh, what about this, what about that, it's not acceptable, we can't go on, we can't move forward without having done something on this". Project manager: "Yes, I hear what you're saying, but in the interest of scope, time, cost, we're not going to do that." Gatekeeper: "Okay, sorry Mr Intellectual Property Manager, but we're going to carry on anyway".

In addition to having had formal stage-gate meetings like the one described above where important decisions were made, it was standard practice for smaller functional teams, such as the software team, to frequently get together to discuss issues and solve problems - "so there'd be a kind of mini brainstorming even though it wasn't formal, let's have a meeting to discuss this and just get people's inputs and thoughts on this and that. Usually you'd discard most of them and sometimes it's just, yes there was only one way, sometimes there was a couple of ways then it was a case of how do people overall feel with one or the other" (Participant E4). A third type of meeting, that of cross-functional teams, was held in a more formal and scheduled manner than the spontaneous functional team discussions, at least twice per week (Participant E4).

An issue related to flexibility in tool application is how closely users follow the 'user instructions' of a particular tool (in the absence of a formal set of user instructions, the term refers to the generally accepted way for using a tool). Once again there appears to be two basic situations: Those tools that people use on a frequent basis and that they are quite familiar with, they would use without consulting any prescriptive text - "most of the tools I use day in, day out I guess you get your own way of using things. I guess it's just like Microsoft Office and Excel, whatever you know how to sort of do what you need to do on it and you just continue doing that", "most of the time I was doing 'marketing plans', or 'computer analysis', it was sort of, I don't know if there is a right way of doing that, everyone has their own templates and things and we've got our own templates here at [Company E] and I sort of used my own in that regard" (Participant E5). "Design of experiments, basically as I said, we don't necessarily follow to the letter the strict protocol but we do our own 'design of experiments'" (Participant E2). "There are certainly some tools and methods that I'm very familiar with and I will just pick up and use, full stop" (Participant E4).

Whereas tools that were infrequently used or used for the first time, or having a considerable level of complexity, required users to consult the ‘user instructions’ - “bug fixing and our ‘change control system’ were quite foreign to me at the start. I really had to learn how to use that and follow the rules there” (Participant E5). Participant E4: “I guess if I was using a tool that I wasn’t familiar with then I would certainly play around with it and perhaps do some reading, maybe set up some test data just to see how it works, and sort out its limitations”, citing the example of ‘Open Workbench’: “which I’d never used before, so there was a learning curve to do that”. Furthermore, tools that are used by several members across different functional areas also require more adherence to the rules than tools used by single members only - “The one key tool that I did use, and you have to follow the rules, is the ‘ROI model’, which is from finance. That is a template that everyone uses for their projects and I had to use that in conjunction with the Programme Manager from an engineering point of view, because he had to fill in the staff and the hours development cost, capex, and that sort of thing. Whereas my inputs to that were the sales volumes, costs, sale price, those type things” (Participant E5).

Another facet of flexibility is the freedom or ability of a user to adapt or modify a tool to better suit particular circumstances. At Company E this happens more often than not - “we have refined them [tools] and I guess that’s why I say a lot of these things [tools] are our own version of them”, “You know if you asked have I done an official ‘design of experiment’ I’d say no, I haven’t. But I’ve done our own version of a study to try and achieve a similar sort of outcome or understanding I guess of the product” (Participant E2). “Most of the things we do we are customising the way that we do it to get it to best suit our needs and get the best result in the shortest time possible”, “Okay, well how can we make this most useful for us? We will massage it and manipulate it and do in effect what is useful to us, what gives us the answers that are applicable to the problems that we’re facing, which are many” (Participant E2). “Risk analysis was an example where we used a sort of a fairly formal risk assessment and management process, with a quite extensive matrix and all that, which just got too hard. We adapted it, we made it pragmatic, run by a Kiwi bloke who just couldn’t be bothered with all of this complicated stuff. And it worked really well” (Participant E1). “I did [modify tools]. If I look at ‘competitor analysis’, we basically have a template of what people like to see and whatever, but I take that and changed it to how I wanted to present our analysis against all our competitors” (Participant E5). Participant E5 offers a very specific reason for modifying tools: “Because different products have different attributes and so I changed a lot of things around on that, what I wanted to show. Everyone would do that on their product. In the next type of project, I will use the same type of format, but I think I will use it a bit differently in that the next project we're on is not just for a hand portable, it's for a whole, complete system. So I'll probably add our [products] and our infrastructure features into there as well."

While tools are often modified, the actual modifications are not formally documented or recorded for future reference - "[we don't record tool changes] not so much because every project is different, it's more because of that other aspect that, we would love to, and have every intention at the time, to go back and modify tools, processes, procedures, policies and all that that are in our quality system to reflect what we've just learned, but we hardly ever do" (Participant E1). The unfortunate consequence of this is that learning that took place in one project is not necessarily successfully transferred to subsequent projects that may involve different people - "with both these people [project managers of new projects] I had, probably all up, maybe a week amongst us, where I basically passed on what I learned in this project, verbally, through the odd document and whatever, to the next project. So we had a bit of a sort of a debrief and passing on some learnings, but that's not reflected in any of our quality procedures" (Participant E1).

During the interview the five participants were asked to rate the thoroughness levels to which they used their tools during the project on a 5-point Likert-type scale, where 1 = superficially and 5 = substantially. The following counts were obtained for each of the five ratings: 1:- 2 counts; 2:- 17 counts; 3:- 26 counts; 4:- 54 counts; 5:- 32 counts. Fourteen tools received 2-ratings and below (indicating superficial usage). They were 'collaborative product development', 'value added/value engineering', 'Porter's 5 forces', 'scenario planning', 'TRIZ', engineering document management system, fault tree analysis, selection criteria, lead user, 'concept testing', 'beta testing', 'limited roll-out', 'marketing plan' and 'voice-of-the-customer'. Six of these tools also scored low familiarity ratings. These results indicate that, generally speaking, in terms of thoroughness of use the five participants of Company E use tools moderately to substantially.

6.5.6 Tool Experiences

One tool user expressed, from personal experience, a potential danger in prescribing tool use that may necessitate frequent referral to user manuals in order to operate it effectively - "I like to think of a tool that I can use without reading the manual because I'm a real bloke you see and yeah and if you don't use it often that is a trap you fall into" (Participant E3). This suggests that men in general do not like referring to user instructions, are not inclined to do so, and consequently may end up using a tool, but using it perhaps incorrectly or ineffectively. The user cites the company's 'document management system' as an example of such a tool.

When a tool is adopted by one functional department and not by another in a situation where communication is required in terms of shared information, it can potentially cause problems. Participant E3 explains that the engineering department makes extensive use of the TIMS tool for issue management, while the manufacturing department don't – "it doesn't make the process as smooth [as it could potentially be]". "There might be a manufacturing issue, well an issue in a system and it doesn't get picked up in manufacturing or vice versa, manufacturing hasn't got a good way of conveying things that they want to tell us".

Participant E5 comments on the huge amount of learning that took place for him personally over the course of the project: "I was definitely very, very green, on the whole new product development cycle. And of course, stemming from that are the tools that are used within there. I mean, there are a lot of things that guys who've been here for a long time, talking about, and it would take me, I'm like, well, you don't want to ask a stupid question, but, 'What is that? Why are we using it?' You learn it now, and now I've got a pretty good understanding of most of these things, that'll hopefully help."

Thinking back, the project manager recalls three aspects of the project where things went wrong. The first was a configuration system that was supposed to assign unique numbers to products, but it did not work so well and eventually it broke down completely. After a period of about one year this tool was abandoned and replaced with a simpler system. A second problematic situation was when it was decided (by people outside the project team) that global positioning technology had to be built into the product, at a stage when many design decisions have already been committed to. This was a classic case of breaking the rules of the NPI process to the detriment of some, as this placed lots of pressure on designers, and eventually the idea was let go (this feature is now in the scope for the next generation radio).

Having completed the project, the project manager is able to identify weaknesses in the system. Project reviews, which take place at each gate and at the completion of a project, is neither done effectively, nor efficiently. The problem is that project data and summaries are not captured in a concise manner – "basically, there's a whole stack of different documents and spreadsheets and whatever else. In essence, there probably is a folder on the network, full of stuff which represented the contract book. It wasn't very nice. I couldn't just print it out and give it to somebody." Because of this it is very difficult for the external reviewers to assess a project – "because it's all over the place, the project stuff, the budget, the plans, the risks, the scope definitions, all that sort of stuff, they have a hell of a job." It appears this problem also manifests itself in other areas: "Creating enduring assets for our learnings, we're not doing very well", "so knowledge management, we're doing it via people alone, really. Well almost entirely via people. Not via any sort of formal systems, or recording of information or anything like that". Other participants echo the same sentiment: "Information management I think we are a bit weak in, not that I am an expert on this sort of stuff myself" (Participant E3), "information was stored in different ways and different places so some of it you could get through an Intranet Wiki page, others were hidden away in folders within a particular department, on a particular department's server so and therefore actually to get it all together was not simple and sometimes you found that you didn't actually have the necessary permissions to get to some of the places that people used" (Participant E4).

Another area of perceived weakness is the fuzzy front end of the NPI process – "So that from a marketing point of view I think that, yeah, we could do a lot better in getting our requirements and research done up front" (Participant E5); "we all have the impression that in this whole area, we're not doing very well. I'm not sure whether that's due to any particular tools or a lack thereof. New product development projects have maybe ninety something per cent of the staff on the team that are technical, engineering, product design related people. Experts in that, and we have very few sort of more soft, customer, market assessment, type of people. [In this project] we may have had two people, well one part time and one almost full time person to do all this. Which means we're not touching on a lot of these fuzzy front end tools and the processes and whatever, but we're not doing any of them to any great extent" (Participant E1).

On the positive side, the project manager was very satisfied with the teamwork and commitment showed by all members. This particular project was the first in the company's history of reasonable size that was on time and met both budget and performance specifications. "So we had several people who were starting new projects actually came and talked to us how, what had we done this time that was different to previous projects and how well it worked" (Participant E4).

7 CASE STUDY ANALYSIS AND FINDINGS

This chapter presents the cross-case synthesis of the five company case studies summarised in the previous chapter. It draws from the original raw empirical data that I collected from the five participating organisations, the narrative summaries of Chapter 6, and the coded NVivo data files. My interpretation and discussion of the results follow the sequence of this study's investigative questions, which fall into six main sections:

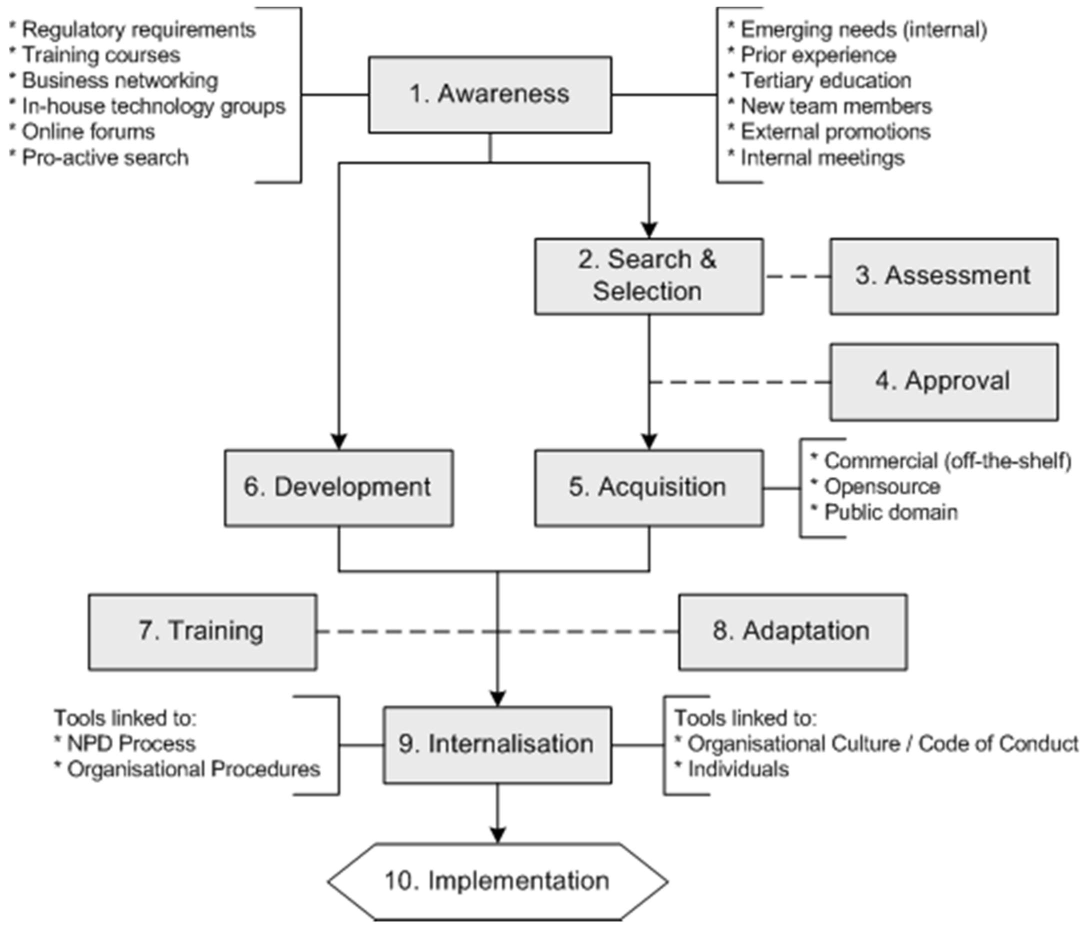
7.1 Tool adoption process
7.2 Obstacles to tool adoption
7.3 Tool familiarity
7.4 Reasons for tool use
7.5 Tool usage
7.6 Practitioner experiences

In the sections that follow, I try to discuss topics under the specified headings, but since the various issues are so interrelated, there is often considerable overlap among the sections.

7.1 Tool Adoption Process

Having closely studied the five participating firms in this study, I could find no evidence of an overriding process guiding the adoption of tools. While I observed plenty of loose-standing piecemeal activities, the activity of adopting tools very much happens in a haphazard fashion. A possible reason for its absence is that, although firms constantly and undeniably engage in this 'process' (the tools they apply are evidence of this), it appears tool adoption is one of those things that just happens without special consideration within companies, most aspects of it in a very informal manner - as Participant D1 states: "tool adoption is a pretty informal process". Only in specific instances where significant capital outlays are required, or where demands are made by external regulatory bodies, will aspects of the total process be more formalised. Despite the fact that none of the companies in the sample has a specific process that they follow for adopting tools, all the participants have some knowledge of how it normally works in their organisations and were able to provide me with 43 references within the coded NVivo section 'tool adoption process'. Although there are minor differences in what they describe, the similarities were sufficient to identify a 'generic' tool adoption process (see Figure 35) that depicts how tools are currently adopted.

Figure 35: Empirically observed phases in the tool adoption process



Note: dotted lines indicate optional phases

I identified nine possible phases in this process before the Implementation (phase 10), some of which can be avoided depending on specific circumstances. Phases that are linked by dotted lines represent those exceptional instances where additional action may be required. In this section I describe the principle phases in this generic process. Where I notice significant differences between the five cases, I mention it explicitly.

- *Phase 1: Tool awareness*. This is the first phase or step in the process when practitioners become aware of the existence or availability of tools for the first time. Before I describe this step in more detail, I first comment on the tool awareness levels among practitioners in my study.

  All five project managers whom I interviewed were tertiary educated in some discipline of engineering and seemed to be well aware of most of the 76 tools I refer to in the survey, and so did most of the other participants during the interviews. However, as I was present when two of the participants completed the online survey I noticed that they frequently consulted the help menu in the survey where I provided brief descriptions of the various tools. In my field notes, I recorded several instances where participants made comments such as "hmmm I see, we used something similar", and "not exactly, but close enough" while reading the tool definitions. I also made a point during the interviews with the three remaining project managers to ask whether they consulted the help menu when completing the survey, upon which they all responded in the affirmative, e.g. Participant B1: "yeah, definitely, I used it a lot to refresh my memory". It thus appears that, while practitioners do remember the names of most of the tools and are aware of their existence, they feel unsure if their understanding of a particular tool is actually what the tool really is about, hence the need to 'refresh the memory'.

As my survey questionnaire did not investigate any aspects of tool awareness, I wanted to get a rough idea if there was a relationship between 12 of the very low-adoption tools in Figure 20 and Figure 21 ('synectics', 'TRIZ', 'Delphi method', 'MBAF', 'fault tree analysis', 'market prediction models', 'real options theory', 'expert systems', 'diffusion models', 'discrete choice', 'conjoint analysis' and 'ethnography') and awareness of these tools. During the interviews, I therefore asked the participants if they were aware of these tools. It turned out most of the participants were unaware of these tools, except perhaps for fault tree analysis and expert systems for which at least there was name recognition, but zero familiarity (more about tool familiarity in Section 7.3).

Awareness levels aside, there appear to be many 'triggers' or opportunities for practitioners to be exposed to tools. As it is common for NPD practitioners to be tertiary educated, universities or polytechnics are the first obvious means or place of exposure to many of the tools these people will encounter in their careers. Most of the teams in this study increased their level of tool awareness by recruiting new members with significant past experience in NPD and knowledge of specific tools - e.g. new recruit in Company A: "Well don't you know what software configuration management is?" (Participant A3). Another example is Company D that appointed a project manager who previously worked at a world-class NPD firm that applied many of Toyota's 'best practices', and this person's experience rubbed off significantly on the rest of the team.

It seems commonplace for teams to discuss practices and tools informally among themselves during internal meetings or via online forums. With regard to commercial tools, only Company E (by far the largest of the five), reported incidents where sales professionals would pre-emptively approach the company to promote a particular proprietary tool or do a sales pitch. It could be that the smaller companies are seen by vendors as being too small to justify such effort, as Participant C1 comments: "some of these tools [commercial tools] are very expensive and it's not really cost effective for a small company to use. It's more a package that you would buy as a big company...". Therefore, unless practitioners in small companies make the effort themselves to go looking for relatively expensive proprietary tools, they are unlikely to be made aware by the promotional activities of vendors. Company E is also the only example where specialist in-house groups, in this case a dedicated Technology Group, do frequent presentations to company staff regarding new technologies and tools, commercial or other. Obviously only larger companies that are involved in many NPD projects at a time can afford and justify this kind of dedicated service.

Several of the firms in this study, by the nature of the industries they are working in, were 'forced' by regulatory bodies to comply with certain practice, including the use of specific tools such as 'issue management', 'engineering document management system', and 'quality systems', which they then internalised.

Only participants from Companies C and E said they were sometimes pro-actively looking for new tools - "we always look for new ways" (Participant C1). In many more instances practitioners would, when faced with emerging problems for which they do not already possess suitable tools, re-actively go searching for potential solutions in the form of new ideas, starting points for solving problems, appropriate existing tools, or practices (Search and Selection Phases). It is during the search phase, that practitioners may become aware of tools that can potentially assist them with the job at hand. "[We adopted new tools] when we suddenly realised we haven't got any tools for a particular problem" (Participant E4). Alternatively, they could opt for developing their own custom tool (Development Phase).

- *Phases 2, 3, 4 and 5: Search & Selection, Assessment, Approval and Acquisition.* These four phases apply to existing tools that have not yet been internalised by the firm, which may include commercial (off the shelf) tools, 'opensource' tools, and tools that are freely available in the public domain. When it is uncertain which existing tool would be appropriate for a particular job, practitioners would start a search using the Internet and perhaps talk to other people in the industry. This can sometimes be a difficult task, as Participant B3 explains: “the other part that we are having problem with is actually identifying something that is suitable and affordable [in terms of financial outlays] for an enterprise of our size”, and “we are still looking for an inventory management system” (Participant C1). The word ‘suitable’, in the context of Company B, refers to the requirement for an ERP software package and implicates four things. Participant B3 demands that it not be overly complicated, thus making it difficult to learn. It should not come with too many ‘bells and whistles’, as a small firm such as themselves may not require all that functionality, and having to pay for what they don’t want. Thirdly, it has to be able to integrate effectively with existing systems to avoid duplication of data entry. In the final instance, Participant B3 recalls situations where other companies were contractually locked in with certain vendors for specified periods of time despite their desire to exit the agreement because the acquired software tool turned out to be unsuitable. Because of these factors, Participant B3 is following a very cautious approach to making sure his firm procures ‘something that is suitable’. Viewed alongside Participant C1’s earlier comment that it is sometimes not cost-effective for small firms to procure commercial tools, it is clear that smaller firms are often at a disadvantage to larger firms in terms of accessibility of more costly, and presumably, more sophisticated tools. Tools that are relatively inexpensive, though, would normally not require a formal assessment and none of the participants could recall situations where they short-listed and evaluated several alternatives alongside each other. There is also no approval process for relatively inexpensive tools, but tools approaching NZD1,000 would normally require approval by either the project manager or a line manager. Only the participants of Company E once took part in a needs assessment exercise that involved the adoption of a major tool that was to be rolled out company wide.

- *Phase 6: Development.* Participants provided a number of reasons why they would develop their own tools rather than acquire something existing:
  - ‘Suffering’ from the ‘not-invented-here’ syndrome (Company A). This refers to the natural tendency of people to mistrust things that originate elsewhere, believing that they can make it better than what is currently available from external sources.

- Spreadsheet-based tools are useful and easy to develop and customise (Companies A and C). This includes situations where (1) a user purposely designs a tool from first principles (e.g. Company C's comparative pricing models); (2) a user develops what is considered a generic tool based on his/her own interpretation of the tool (e.g. Company B's financial model), and (3) a user customises an existing spreadsheet to suit particular circumstances (e.g. Company E's 'design of experiment' spreadsheet).
- Unattainable - some situations require very specific applications for which nothing is available (Company A).
- Automation - custom-designed tools are useful for automating company specific tasks and processes (Company C).
- Speed - building your own tool is often quicker than buying and configuring something off-the shelf (Company C) - assuming that a team is capable of doing this.
- Custom-designed tools are more flexible than purposely-designed tools (Company E). However, they are not always meeting the requirements - "we have our own little system which is on Excel which is not very successful, but we are still looking for an inventory management system" (Interviewee C1).

A point to note at this stage is that the activity of custom-designing tools is currently missing from Figure 8, p. 68 (Integrating NPD praxis, practices and practitioners). This is because the original framework was developed to depict constructs in the field of strategy, where supposedly new tools are not developed from scratch during project implementation. Hence, a further modification which reflects custom-designing of tools is appropriate, perhaps by means of a single arrow originating from within the individual project level (the bottom plane), and extending into the top plane where it is internalised within the firm's set of NPD practices.

- *Phase 7: Training.* None of the small companies (A to D) provide formal tool training themselves. These companies rely on individuals to master tools by themselves (through self-study using the Internet or books on the topic) or become acquainted with tools through informal on-the-job training. Past research showed that lack of training is common among small firms (Barnett & Storey, 2000). On occasion, management may send one or two people on an externally offered training course, "there were a number of us that went on a course early on this year" (Participant D1). Local and national government often provide and subsidise special training courses such as 'lean manufacturing'. The same conditions described above also apply to Company E, but practitioners also frequently receive formal tool training from specialist groups within the firm when new tools are introduced, or per individual request for training on any particular tool.

- *Phase 8: Tool adaptation.* I distinguish between two types of tool adaptation. The first type takes place in the adoption phase when a new tool has been acquired by the firm and the team, or an individual user, decides to improvise it before starting to use it ‘to better meet the needs of a particular situation’. An example would be Company A’s ‘TRAC’ tool. The company originally acquired this ‘opensource’ application and immediately decided to customise it by adding additional features and functionality “to better fit in with our culture”. The second type of adaptation occurs during implementation when practitioners, perhaps conveniently, interpret tools according to their individual preferences and levels of tool familiarity. I discuss this second form of adaptation in detail in Section 7.5. Unless it is impossible to tweak (e.g. ‘CAD’), most acquired tools are adapted or configured in some way - “customising tools are fairly important, you’ve got to be able to kind of sometimes fit a square peg in a square hole, but all you got is a round tool, and you’ve got to shape it a bit so it fits in that square hole” (Participant A3). I provide specific examples in Section 7.5.

- *Phase 9: Internalisation of tools*. The Free Dictionary defines ‘internalise’ as “to make internal, personal, or subjective” and “to take in and make an integral part of one’s attitudes or beliefs” (TheFreeDictionary, 2010). In the context of NPD, I define tool internalisation as ‘the various mechanisms through which NPD practitioners and sometimes management, within an organisation, integrate and promote both acquired and internally developed tools for use by teams and individuals’. These mechanisms, which I detail below, can exist by design, by default, or by a combination of both.

  From the participants’ accounts and prior research, notably Whittington’s (2006), I was able to identify four such ‘link mechanisms’ of tool internalisation in companies. The links may exist in a deliberate manner (when they are explicitly prescribed) or merely be in association with something. The first two link mechanisms, as identified and discussed by Whittington, are operating procedures and culture. The latter happens when firms succeed in establishing a written or unwritten code of conduct or workmanship that ultimately becomes part of the organisation culture, and associating certain tools with this code (e.g. ‘continuous improvement’ and ‘5S’). Tools ‘linked’ in this manner are not enforced by management or anybody else - “you got to kind of get buy-in from the guys”, until such time they automatically stick - “it’s a matter of just reinforcing these things all the time until it becomes a culture in the shop” (Participant B2), “I sort of knew I had to use those tools, as there is pressure from the group, the core team” (Participant E5).

In the context of NPD, I consider an operating procedure to mean a single activity that may consist of multiple steps performed to accomplish a specific outcome. For example, a firm may have established an idea generation procedure of which typical steps could include the capturing of ideas in a central repository, initial screening of ideas, assessing ideas, developing and selecting ideas, etc. At specific points, this procedure may call on the use of several tools such as a Web-based idea capturing tool, and brainstorming to facilitate or support an activity. The outcome of this procedure is a potentially feasible idea that could be implemented by the company. A process, on the other hand, is a set of procedures that follow a particular sequence to bring about a result. An obvious example is the NPD process that may consist of numerous procedures such as idea generation, concept testing, industrial design, prototyping, production, etc. In practice, firms may achieve the desired results (i.e. develop a new product) through successful implementation of many procedures which may or may not have been formally linked via a process. Even the procedures themselves may or may not have been formally described. Companies A and B are examples of firms that ‘followed no standard approach’ to developing the products under consideration, implying the absence of a formal NPD process, yet managed to launch successful products nonetheless by executing a series of formal and informal operating procedures. Examples of tools that have been internalised via operational procedure include ‘portfolio analysis’, ‘engineering document management system’ and ‘Kanban’ (via strategic planning, quality control and inventory control respectively - in this case procedures that operate independently of any specific NPD project or programme). As I have found that Companies C, D and E are linking some tools directly to stages and sub-stages in their NPD processes (e.g. ‘stage gates’, ‘design review meetings’, ‘alpha prototype’), I include the NPD process as a third mechanism for internalising NPD tools.

Lastly, I was given many accounts by participants of tools that simply reside with individuals - tools “existing at an ad-hoc level”, “tools floating around on thin air” (Participant C2). Such tools are neither linked to any process or procedure, nor associated with organisational culture or recorded in any place, yet are frequently used by practitioners.

Typical examples of such tools would be the smaller, individualised tools such as spreadsheets or very niche applications that practitioners draw upon, perhaps in unique situations appropriate to one project, but not to another.

Table 31 summarises the characteristics of the predominant internalisation mechanisms for the individual companies in this study that existed at the time when the projects were undertaken. In terms of tools linked to the NPD process, there are significant differences among the five companies. The two smallest firms have neither formal nor informal NPD processes in place and hence cannot use this mechanism for internalising tools. For the three remaining companies who do have NPD processes, tools are only associated with these processes but not explicitly linked (except marginally so for a few mandatory tools in Companies C and E). All the firms in the study commonly deploy the next link mechanism, operating procedures, especially so Companies B and E that were in existence for several years prior to the development of the product under consideration. The linking of tools to a code of conduct is another linking mechanism that appears to take time to establish. Once again, the two older companies (B and E) do well in this regard, while the younger companies show clear signs of moving in this direction. A final observation is that, in all participating firms, certain tools reside with individuals only (i.e. these tools are not linked via any of the three other mechanisms).

Table 31. Predominant characteristics of tool internalisation

(interview extracts from NVivo)

Link mechanisms	Company A	Company B	Company C	Company D	Company E
NPD Process (first identified in this study)	No standard approach to new product development	No standard approach to new product development (although there was some agreement among members about the tasks required to complete the project)	5-stage process (used extensively) Tools not formally linked to process but moderately associated with it, especially mandatory tools imposed by regulatory requirements (e.g. documentation control, risk management)	Informal process (used superficially) Tools not linked to process "Pretty loose at the time" But "part of the process" - some association with process	Formal 5-stage process (used extensively) Tools not necessarily linked to process except for few mandatory ones Tool selection "largely up to us"
Operating Procedures (first identified by Whittington (2006))	'Cargo Cult' phenomenon - deliberate attempt to make tools part of the firm's procedures	Tools mainly linked to operations procedures e.g. CAD, Kanban, configuration management Driven by 'paperwork'	Some tools are well integrated into organisational procedures	Tools associated with formal and informal procedures	Tools formally and informally linked to long-established procedures
Organisational culture (first identified by Whittington (2006))	Slowly developing e.g. TRAC was acquired in a way "to fit our culture"	Very strong culture "reinforcing the use of tools" e.g. continuous improvement, tool storage, workplace cleanliness Get buy-in from users Gradual exposure	Instantly inherited a culture of outstanding professionalism from holding company that includes expectations of appropriate tool usage	Strongly developed in one area in particular: the firm's differentiator strategy with regard to aesthetics. Many design and marketing tools associated with this mechanism	Strong sense of tool application in line with company culture - "this is our way of doing it"
Individual practitioners (first identified in this study)	Automatic integration Unconsciously Mostly engineering and marketing tools Server repository from which tools are selected as and when required	Mostly engineering, project strategy and general management tools	Exist at an 'ad-hoc' level Tools "floating around on thin air" Moderately high use of engineering, team support tools	New members bringing in tools from the outside High usage of engineering, general management and financial tools	Many smaller tools, used by individuals

7.2 OBSTACLES TO TOOL ADOPTION

With the exception of Company E, in the online survey all the other firms indicated ‘insufficient budget’ as one of the main obstacles to tool adoption. Although past research (see Section 2.6.3, p. 49) indicated that lack of financial resource is a common problem among firms of any size, it seems reasonable to conclude that it possibly is an even bigger problem for smaller firms.

In addition to mentioning the cost barrier, several participants insightfully point out some less obvious factors related to resource constraints. The high-perceived ongoing management effort associated with some tools makes them very unattractive. Participant A3 cites ‘heavy weight’ project management as an example of a tool just being too labour intensive despite the potential benefits it may bring. Evidently, due to the small size of the firm they cannot afford the luxury of having a dedicated person attending this tool (which may very well be possible for a larger firm), or even want to expend some time from any team member to drive this tool.

Participants B3 and C1 believe that when you are facing limited budget situations, it can be very hard to find suitable tools that are affordable to small firms. Both firms have been in the market for enterprise software for significant periods of time, but have been unable thus far to find something cost-effective. Participant B3’s extreme caution to ‘locking-in’ – as he refers to it - to an expensive tool and then getting it wrong in the choice of tool, can also be seen as an important obstacle to tool adoption, especially among small firms. One mistake in this regard can easily jeopardise a whole project or even worse, put the whole company at risk. Participant D1 reckons ‘opportunity constraints’ is a barrier somewhat unique to smaller firms, meaning practitioners in small firms often lack ‘exposure avenues’ to existing or emerging tools. In bigger firms, employees get more chances to visit foreign companies, such as Toyota, to observe and learn about their practices and tools (Participant D1 personally experienced this in a larger company that he worked for prior to working for Company D). Another example mentioned previously is the tendency for tool promoters to ignore small firms, as they perceive them as unlikely customers because of their small size and very limited budgets. Time constraints can sometimes make it very difficult to find a time convenient to all team members, who are usually already stretched to the limit with project-related activities, to do the necessary due diligence on a tool, undergo training, help with its implementation, and be involved with the tool's ongoing management - "some tools can really be a huge undertake" (Participant E1). In view of these resource constraints, it is not uncommon for firms to delay the adoption of certain tools, for example, Company B has put the implementation of 'lean manufacturing' on hold for a considerable time.

Both companies D and E cite people-related obstacles to tool adoption. An example is when individuals exhibit a resistance to change (change brought about by the use of a tool), showing complacency - "for many years we were quite successful without doing any of that, so, why do we do this?" (Participant E1). Another example is bias against certain tools that are not perceived to be able to yield any benefit - "[teambuilding] - they [engineers] just think it is a waste of time, they tend to view it as 'treehugging'" (Participant E1).

Participant D3 raises a final obstacle to tool adoption. His view is that unstructured development, where no direction is provided by some form of process, causes teams to adopt fewer tools than otherwise. This observation provides strong support for my survey questionnaire finding that firms with more elaborate NPD processes are more likely to adopt and use more tools in their projects than firms that have no or poorly developed processes (see Figure 18, p. 110).

7.3 TOOL FAMILIARITY

During the interviews with 17 participants from five different companies, I asked participants to rate the level of familiarity for those tools that they personally used during the project. Ratings were done on a five-point Likert-type scale where one indicates the lowest rating and five the highest rating. In the first instance my intention was to see what fraction of the tools practitioners used, they were relatively unfamiliar with. I therefore calculated, for each company, the ratios of low-familiarity tools used (ratings of 1 and 2) to the total number of tools used, and came up with these findings: Company A: 12.5%; B: 14.8%; C: 0% (none of the three participants indicated unfamiliarity at the 1 and 2 rating levels); D: 7.3%, and E: 15.1%. Without calculating the average among the five companies (as this was not meant to be a quantitative exercise), I postulate that practitioners are very unfamiliar with 10-15% of the tools they use (ratings of one and two). I next identified the low-familiarity tools among the four companies (I excluded Company C from this exercise as it did not deliver any 1 or 2 ratings). There were 30 in total, but contrary to expectation, there were only two tools in common among the four companies. They were ‘teambuilding’ (common among three companies), and ‘engineering document management system’ (common between two companies). The remaining 28 low-familiarity tools were each unique to one of four companies. This shows that, when it comes to tools practitioners use within the five case study companies, practitioners in different companies are unfamiliar with different tools - there is not a consistent pattern with regard to the lack of knowledge of specific tools.

Assessing the relation between tool familiarity and thoroughness of use

> *$H2^{thor}$: There are no differences among the observed means in thoroughness of tool use at different levels of tool familiarity*

My survey results indicate a general positive correlation between thoroughness of tool use and performance improvement (see Section 5.2.15). As my survey did not measure tool familiarity, and since I was keen to investigate the relationship between tool familiarity and thoroughness of use, I used the case study opportunity to collect some relevant data that enabled me to test hypothesis $H2^{thor}$ in this regard.

Consequently, I also asked the 17 participants during the interviews to rate the degree of thoroughness to which they applied those tools they have personally used. Once again, ratings were done on a five-point Likert-type scale where one indicates superficial usage and five substantial usage. Table 32 and Figure 36 summarise the main descriptives of the findings when I compared various levels of tool familiarity with the degree of thoroughness in use.

Table 32: Familiarity versus thoroughness of tool use - descriptives

Familiarity level	Thoroughness				95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
1 (low)	21	2.24	1.136	.248	1.72	2.76
2	39	2.90	1.142	.183	2.53	3.27
3 (moderate)	74	3.15	.917	.107	2.94	3.36
4	133	3.40	1.058	.092	3.22	3.58
5 (high)	106	4.11	1.098	.107	3.90	4.32
Total	373	3.43	1.168	.060	3.32	3.55

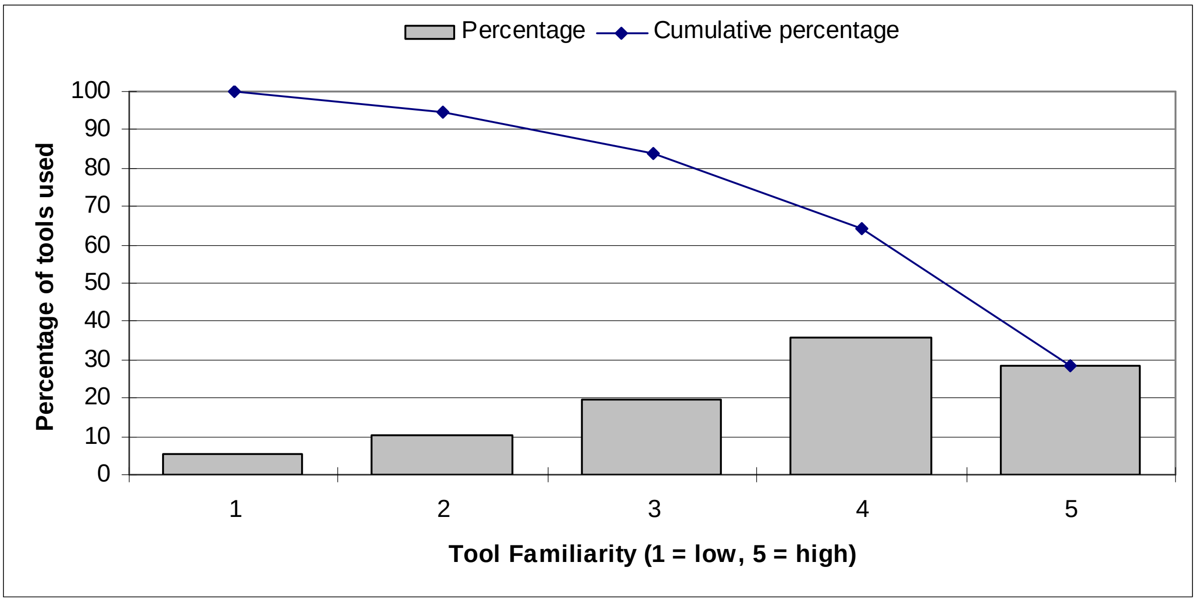
A visual inspection of the data in Table 32 confirms the almost intuitive expectation that thoroughness of tool use will improve as a user’s level of familiarity with a tool increases.

Before testing hypothesis $H2^{thor}$ with a one-way ANOVA, I first used Levene's test to prove that the variances in thoroughness (Table 32) are not significantly different, implying that I have not violated one of the assumptions of ANOVA. From Table 33 it can be seen that the value of Sig. is not less than .05 (Sig. = .311), which renders Levene's test insignificant. Hence, the results of Table 34 are valid (Sig. combined for F = 21.55 is less than .05), and I am able to reject the null hypothesis.

Table 33: Test of homogeneity of variances

Levene Statistic	df1	df2	Sig.
1.153	4	368	.331

Figure 36. Familiarity levels of tool used in a particular project



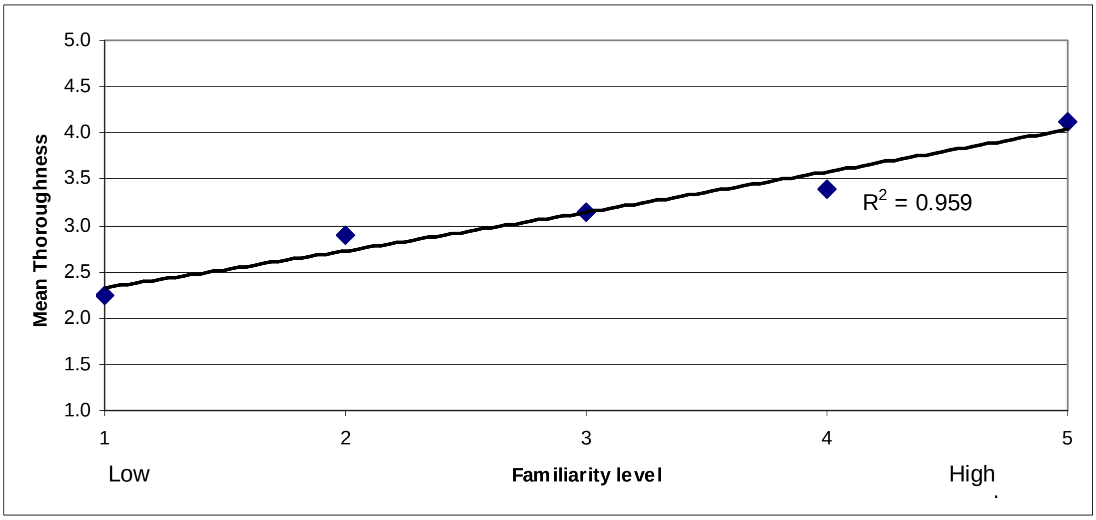
It appears from Figure 36 that users are quite familiar with the tools they use, which indicates familiarity levels of four or five for close to 70% of tools that were used in a particular project. For 20% of tools, users indicate neither low nor high familiarity (a tool familiarity rating of three), while 16% of tools were used in projects despite very low levels in tool familiarity among users of such tools (tool familiarity ratings of one and two).

Table 34: Familiarity versus thoroughness of tool use - ANOVA

			F	Sig.
Between Groups		(Combined)	21.554	.000
	Linear Term	Unweighted	61.871	.000
		Weighted	80.274	.000
		Deviation	1.980	.117
	Quadratic Term	Unweighted	.034	.854
		Weighted	1.534	.216
		Deviation	2.203	.112

Knowing that the differences in mean thoroughness levels were significant for varying levels of familiarity, I analysed whether the relationship between familiarity and thoroughness is linear or quadratic. For the linear trend the F-ratio is 61.871 and this value is significant at the .000 level. The same cannot be said for the quadratic trend (for which the unweighted F-value is less than one and Sig. = .854, which clearly indicates non-significance). Therefore, I can say that as users become more familiar with the tools they use, they proportionately apply these tools more thoroughly. This finding is not only substantiated by the results of Table 34, but also by the high value of $R^2 = 0.959$ of the trend line in Figure 37.

Figure 37: Familiarity versus mean thoroughness of tool use



7.4 REASONS FOR TOOL USE

> *"Different NPD tools become relevant at different stages of an organisation's development. For example, there are vast differences in a start-up developing a new, disruptive product and launching from scratch, to a well-established company with a portfolio of products that is looking towards implementing or improving their NPD strategy."* Participant A3

This comment from Participant A3 was very significant as it first drew my attention to the similar evolving patterns in tool needs among my sample of firms, not only during the life cycles of the projects I studied, but also following the periods after product launch and the initiation of subsequent projects. As mentioned before, a major differentiator in my case studies is the small size of companies studied, with the exception of Company E that serves as a large company reference. Because of the technology nature of the projects involved, all four cases A to D can be considered technology start-ups, or New Technology-based Firms (NTBFs) as they are often referred to. Furthermore, companies A to D were all novices in the field of NPD: Companies A and D were both NTBFs, purposely formed to take a product idea to market (which took them 24 and 20 months respectively). Company C was also a technology start-up, tasked to develop and launch a new product (which took them 16 months), but since it was a subsidiary of a long-established mother company, it was strongly influenced by existing, established management practices. While Company B had already been in business for several years when they took on the development of their product, it was their first complete NPD project that spanned a period of 12 months, hence the company can also be seen as inexperienced in NPD. Company E, however, is an established firm with many years of NPD experience. The estimated development time for their product was 24 months. Consequently, the 17 practitioners I interviewed reflected on their experiences going back to particular stages in their organisations' development that coincided with the development projects studied here and, in the process, described unfolding situations over roughly the one to three year periods during which the projects ran. Because of this, I was able to observe and describe (below) how practitioners' tool needs changed over time; how they incorporated tools into NPD activity.

In view of this, my analysis of 'tool needs' focuses on what happens within first-time projects executed by new businesses (companies A and D) and new business units (companies B and C), and compares that with a large established business (Company E) executing a project for the n^{th}

time in succession. I started my analysis by viewing the raw data and the case summaries in Chapter 6 as a large sample regardless of the research areas to which they were related to, or the organisations from which it was collected. From this, I empirically derived summaries of four distinguishable sets of prevailing circumstances and conditions that the respective teams faced during the execution of their first and subsequent NPD projects in Table 35, which in no way correspond to or resemble the familiar stages in a typical project's life cycle (initiation, planning, execution and closure). Rather, these sets of conditions depict sequential but overlapping 'tool periods' that unfolded over time as teams gained more experience and firms matured. These sets of changing conditions drove the evolving tool needs of team members, the latter of which I depict in Figure 38 as a hierarchy of tool needs. In principle this tool needs hierarchy functions similar to Maslow's (1943) famous hierarchy of human needs. I next explain the four levels in the tool needs hierarchy (Figure 38) in some detail.

Figure 38: Empirical tool-needs hierarchy for NTBFs

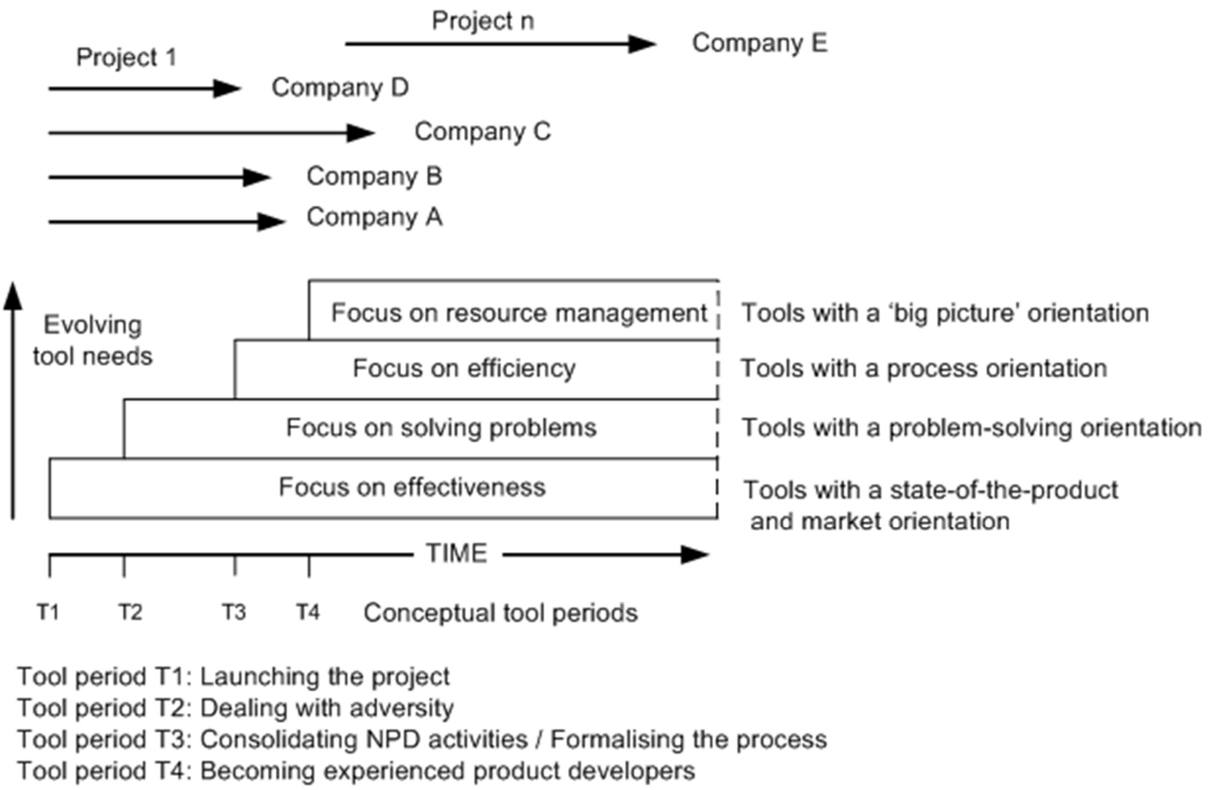


Table 35. Prevailing phase conditions in NPD project evolution

Phase 1: Launching the project (early days)				
Start-up companies (NTBFs)		Start-up 'business units'		Established firm
Company A	Company D	Company B	Company C	Company E
Formation of core team took 12 to 16 months; early days were chaotic; crisis management and fire-fighting; no one really knew what we were doing; start-up culture with plenty of dynamism; trying out many things; lots of pressure on team to perform; main objectives to demonstrate advanced prototype and fulfil early orders & backorders; focus "very much tactical rather than strategic"; product focus - get the job done *	Formation of core team took one year; things were kind of pretty loose at the time; unstructured development; tools used for scoping out the product; we placed a great deal of emphasis on product design, the aesthetics and functionality of the product *	Core team present from the start; time constraints were a big thing; pressure to complete prototype for Melbourne exhibition; task focus; urgency - get on with the job; need to move quickly; thus very little planning; call in tools to get an immediate job done; tool use happened automatically; be effective - call in a tool when a particular activity calls for it; we need to make sure our backs are covered; strong focus on quality workmanship; if it makes sense we run with it *	Apart from marketing person - core team present from the start; industry watchdog imposed compliance factors; FDA import regulations; strong task focus; used only tools necessary to achieve an end result; tools are a means to an end, to get a quicker result; tools are so intrinsically linked with NPD activities; thorough planning right from the start; well- organised *	Core team and supporting infrastructure present from the start; little fanfare; 90% of tools were already internalised at project launch; some tools inseparably linked to activities in the NPD process *
Tool focus: Engineering, design, market research, marketing #	**Tool focus**: Engineering, design, market research, financial analysis #	**Tool focus**: Engineering, design, market research, financial analysis, production #	**Tool focus**: Engineering, design, market research #	

* Coded extracts that emerged from analysis

Classification based on researcher's interpretation of data

Table 32 (continued)

Phase 2: Dealing with adversity				
Start-up companies (NTBFs)		Start-up 'business units'		Established firm
Company A	Company D	Company B	Company C	Company E
Haphazard adoption of tools; frantic communications; reactive response to some pressing unanticipated problems; painful shift; new tools needed outside the scope of initial core team's expertise; Cargo Cult phenomenon - tools for tools sake; some tools not meeting expectations *	Use tools for problem-solving attributes, often reactively; we'd been quite a way into the project… when we actually found we were heading down the wrong path; practiced 'ambulance at the bottom of the cliff' principle; sometimes you don't know you need a tool until problem happens; all of a sudden they would revert to a tool to solve a problem; plenty of friction among different functions; functions operating independently of one another; often tools were put in place reactively after mistakes had been made; some team members resisting the use of tools *	When problems arose, resort to whatever tool was needed; focus on solving immediate problems, nothing more, nothing less; set aside anything considered to be just value-adding but non-critical to task completion *	Develop own tools to satisfy needs; make changes to commercial tools earlier adopted; experience problems with some tools - roadmapping and software versioning tools *	Only about 5% to 10% of tools used during the project were newly adopted because of situations where we suddenly realised we haven't got any tools for a particular problem; resistance among certain team members against use of certain tools (teambuilding); problems around the use of configuration management system; decisions made outside the team that affected everybody - put members under pressure *
Tool focus: Problem solving; new tool development, adapting tools and sorting out tool problems #	**Tool focus**: Problem solving #	**Tool focus**: Problem solving #	**Tool focus**: Problem solving and decision making; new tool development, adapting tools and sorting out tool problems #	

* Coded extracts that emerged from analysis

Classification based on researcher's interpretation of data

Table 32 (continued)

Phase 3: Consolidating work activities/Formalising the process				
Start-up companies (NTBFs)		Start-up 'business units'		Established firm
Company A	Company D	Company B	Company C	Company E
Need for better process and more tools; we need to improve our methodologies; we need to formalise the way we do our development; we need to identify some good tools and we need to make use of them all so that the whole development process is more easily managed; so it takes years of discipline, some years of learning and several bad experiences before we've really taken on board that we do need a more formal and a more organised approach to doing things; tool examples: configuration management, EDMS, IP management, roadmapping, PM; realised the need for working smarter - tools offer efficiencies; investing in systems, programme focus, automation; ongoing efficiency gains *	Team members are constantly encouraged to adopt and use tools to make the whole process, including decision making, more visible and more recorded; putting procedures in place to ensure the end product actually resembles the brief; the need for working smarter: the more complex distribution channels associated with export also created the need for tools to build products smarter; to ensure sustainable and profitable margins - process focus * **Observed weaknesses**: process lacks transparency among members; decision-making process not visible enough; insufficient structure; poor communication lines *	Well-developed manufacturing procedures; as new orders were processed, ongoing procedural improvements were introduced and more tools were brought into the process to drive efficiencies and effectiveness; tools ensure company image is upheld - high quality image; fitting NPD activities into manufacturing environment; practitioners feel compelled to use tools because of quality culture; tools ensure quality is maintained *	These tools are there to help you reduce your cost and reduce your risk and reduce your time for development; we've got a whole raft of internal tools that we've written ourselves to automate things; tools are helpful in carrying out multi-functional activities, letting people wear many hats; follows a formalised communications approach where they have collaborative cross-functional meetings once a week*	Some tools are extensively used because we know they work and they are part of our stage-gate process; well, this is how we do things, this is just culture and I know it works *

* Coded extracts that emerged from analysis

Table 32 (continued)

Phase 4: Becoming experienced product developers				
Start-up companies (NTBFs)		Start-up 'business units'		Established firm
Company A	Company D	Company B	Company C	Company E
Not functioning in this evolutionary phase during initial project Subsequently, practicing agile development where tools are drawn in as needed, employing well-established, independent procedures *	Not functioning in this phase during initial project * **Observed weaknesses**: poor collaboration; team not functioning as a close unit; members lack the complete picture *	Not functioning in this phase during initial project *	There are a whole raft of other tools floating around that some individuals will choose to use and some won't; such optional tools are not critical to the successful execution of the project, but they are still deemed valuable as they add value in one way or another; tools are useful in creating a common language among team members and serving a common platform that provides a systematic way for functioning and working as a team; the excellent way in which the company collaborates with lead users, individual customers, consultants and suppliers *	Because of our relatively huge group size, I sort of knew I had to use those tools, as there is pressure from the group, the core team; people are speaking a common language; tools are not only used with an immediate outcome in mind, but with a longer-term view where future benefits are anticipated; often new tools were sought pro-actively with the expectation, based on experiences with other tools, that they will add value; we were collaborating all the time with different groups, we needed to use tools to keep everyone on the same page *

* Coded extracts that emerged from analysis

Tool period T1: Launching the project

As start-up firms launch their first NPD projects at time T1, team members predominantly draw upon tools that have a 'state-of-the-product' and market orientation. The reason for this 'narrow' tool focus is that this period covers the early formation days of the newly formed business or business unit, and as can be seen from Table 35, participants describe these start-up periods as chaotic, full of crises, lots of pressure on teams to perform, not enough time, tactical rather than strategic, and unstructured. (Side note: as a matter of interest, I notice that the start-up periods in the two start-up business units were less disorganised than the corresponding periods in the two start-up businesses. A likely reason for this is the stabilising associations that the business units have with their mother companies, which the newly formed businesses inevitably cannot have.) Therefore, team members tend to be pre-occupied with the physical product concept and how it evolves into a saleable product. Anything distracting them from 'getting the job done', such as using mission-non-critical tools, is pushed aside - "it can sit on the shelf until I need to use it" (Participant B1). Consequently, engineers and technicians within teams invariably use tools such as 'CAD', 'prototyping' and other mostly technical tools because these tools are so closely integrated with the period's associated activities that people practically cannot do their jobs without these tools. Similarly, the marketing people in teams will use the standard tools in a typical market research toolbox, such as 'needs analysis', 'voice of the customer', 'beta-testing' and 'marketing plan'. Tools 'originating' from other functional areas such as finance (e.g. 'ROI', 'breakeven analysis') and manufacturing (e.g. 'CIM', 'group technology') are also included here. Therefore, as team members cannot be effective without these tools, I use the term 'effectiveness tools' to categorise tools used at this level of operation. As such, effectiveness tools represent the first (bottom) level in the tool needs hierarchy. Users almost automatically select the tools in this category for a particular task. As a side interest, practitioners are generally very familiar with the tools in this category and they tend to use them in a very thorough manner.

Tool period T2: Dealing with adversity

While the use of effectiveness tools continues throughout the project, teams normally find it necessary quite early in the project (tool period T2 in Figure 38) to occasionally revert to tools for emergency reasons (e.g. 'brainstorming', 'focus groups', 'TRIZ', 'design of experiment'), tools that they did not anticipate using, but were forced to use because of some unforeseen circumstances, to help solve unexpected problems or help in making difficult decisions. Often tools are custom-made to solve a particular problem - “when problems arose, the team would resort to whatever tool was needed, off-the-shelf or custom made, to solve it” (Participant B2). While neither novice nor experienced teams are exempt from using tools in this category because of the uncertain nature of NPD, the former tends to draw on such tools only to an extent where the emergency has been resolved. That is, teams would use a tool under these circumstances no more thoroughly than required by the situation, and once this has been achieved, stop using the tool - “we focus on solving immediate problems, nothing more, nothing less” (Participant C1). The more experienced team (Company E) also used problem solving tools reactively - “only about 5% to 10% of tools used during the project were newly adopted because of situations where we suddenly realised we haven’t got any tools for a particular problem” (Participant E1). However, Company E’s team tend to anticipate problem situations in advance and use problem solving tools in a more pro-active manner, and more thoroughly than the novice teams.

Appropriate adverbs for the tools in this phase include ‘emergency’, ‘incidental’, and ‘problem solving’. This level of tool use also includes situations where team members experience problems with particular tools that they have adopted. Normally, they would first revert to fixing the problem with a particular tool though adaptation, but if this is unsuccessful, look out for an alternative.

Tool period T3: Consolidating NPD activities/Formalising the process

Normally, at some stage after tool periods T1 and T2 (see time T3 in Figure 38), perhaps 12 to 18 months after start-up, teams gradually become aware of a third category or level of tools which I refer to as ‘efficiency tools’, for reasons that follow. This happens when novice teams start to realise that there is more to product development than just the product and its customers.

This situation normally transpires when projects become more complex; when more people become involved and managing it becomes more cumbersome; when costs blow out; when members start to realise the importance of tools that can eliminate repetitive processes, improve productivity, help reduce time-to-market and project cost - “we need to identify some good tools and we need to make use of them all so that the whole development process is more easily managed” (Company A). At this stage, teams become more disciplined, procedures are developed for groups of activities and those firms that have NPD processes in place, start paying more attention to them. The use of efficiency tools becomes part of "the way we do things around here" (Company E). Tools in the efficiency category include 'workflow', 'Intranet', 'engineering document management system', 'bug tracking', 'project management', 'enterprise resource planning', 'NPD process', 'stage gates', 'checklists', etc.

As can be seen by the end points of the project arrows in Figure 38, companies A and B completed their first projects having ventured some 'distance' into the third conceptual time period (only paying limited attention to tools in the third hierarchical level). Company D, on the other hand, only became aware of tools of a process orientation towards the end of their first project. While all the companies in this study have since made significant further advances with subsequent projects, it is technically possible for firms to develop and launch successful products using only effectiveness and problem solving tools, or including process tools as cases A, B and D demonstrate. The fact that it is possible to do so does not necessarily imply good or better practice, as I explain with the final tool period T4.

Tool period T4: Becoming experienced product developers

Eventually, perhaps after having completed two or more projects, NPD teams become more experienced and start using some tools pro-actively because of the potential benefits that such tools might bring to the project. Tools in this category are not necessarily critical to achieving a saleable product that meets target specifications; rather, they are tools aimed at optimising the use of resources (resources in this instance refer to project team members, members of the extended project team, collaboration partners, suppliers, customers, tacit and explicit knowledge). 'Resource management' tools have the potential to improve the ways in which team members communicate, cooperate with internal support functions and collaborate with suppliers, customers and sub-contractors during development activities. These tools also help in the sharing and transferring of knowledge between different groups and across projects. Typical tools in this category include 'knowledge management', 'cross-functional teams', 'post launch review', 'post-project review', 'customer satisfaction tracking', 'teambuilding' and 'team launch systems'. Clearly, some tools in this category not only have a current project focus, but have in mind how the programme as a whole, or future projects can benefit, thus having a 'big picture' orientation. Only one of the four teams in my study (Company C) managed to evolve to this level of tool use (at least to some degree) during their first project. Company E, having completed many projects prior to the one in this study, comfortably operates at this level despite having the occasional setbacks. As is evident from case E's write-up (the only company among the five truly operating at this level), conditions in this tool period are by no means perfect. Participant E1 described how they have not updated their well-embedded process for at least ten years, and that it needed urgent revision to better meet the needs of projects of different scope and magnitude. He also mentioned that some experienced team members were still reluctant to buy into certain practices and tools. Despite these issues, the observed maturity of team members in Company E and the stability of its task environment stood out from the first four cases.

I acknowledge that no classification of tool needs is perfect and that another researcher might group reasons for tool use differently. Still, I believe my interpretation of the data, as reflected in Figure 38, is the best possible interpretation, and that it provides new and useful insights into how practitioners' needs for tools evolve over time. In the final chapter, I place this model in relation to comparable concepts in literature to assess the external validity of my findings.

7.5 Tool Usage

Table 36 provides a summary of the key characteristics of tool application within the five participating firms. I compiled this table using coded extracts from my NVivo case file as well as from the case summaries; therefore, most entries can be traced back to their broader context and appropriate examples in Chapter 6.

A comparison of the key characteristics of Companies A to D (the small firms in this study) reveals far greater similarities among the various aspects of tool application than differences. As such, in my summary analysis and discussion of key characteristics below, I treat the first four cases as one entity representing small firms, and highlight noticeable similarities and differences with the larger firm (Company E).

*Table 36: Characteristics of tool application among case-study firms**

Company A No rigid description of a particular tool for a particular task; where possible use different approaches or leverage some of the tools to get a job done; we would try and adapt to what's required; use for a short amount of time just to get things started; "unconscious" integration of tools; tendency to develop own tools; tools were often not used to their full potential; we're very flexible so I don't adhere to any sort of way of working with tools; I devise my own methods because it does get results; hurriedly draw on aspects of tools, not quite as formal or a totally best practice approach; customising tools are important
Company B Almost no prescription of which tools to use; intuitively; automatically; often in a limited way; not too formalised; most of our meetings are stand-up; we use tools the 'Kiwi way'; we don't really apply tools in a rigid way; we throw away the tool book; modifications are in the order of the day (e.g. Kanban); I use scenario planning all the time in my head, without actually doing a matrix; we don't think about tools; TQM: we don't follow a prescription; we absolutely adapt it to suit; we've kind of stolen the principles of some tools and if it makes sense we run with it
Company C Tools not formally linked to process, it's not like in one particular phase you will use this and you will use that tool, it's more like we use a range of tools across different phases; used as a means to an end, to get a quicker result; some tools so intrinsically linked to activities that getting the job done without them is impossible; we do adapt tools; many tools were developed and customised to the firm's very specific requirements – NPD process itself; some tools evolve over time as users become more experienced; other tools have been combined into one; opensource software is preferred as it allows for customisation; very formalised communications approach and use of related tools; heavy reliance on own interpretation of how a tool should be used – we didn't go out and read out how you should use these tools; the way we apply tools is far more intuitive, absolutely; we're not experts in these tools but we know intuitively how to use them, to a certain degree; there are tools that we're not using for their purpose; improvisations not always successful (technology road maps)
Company D Tool use happens as a matter of course, not linked to the process; tools used very much reactively; over time some tools are used more thoroughly as progression is made down the learning curve; often tools are poorly implemented – NPD process, checklists, stage-gates; tool use lacks formality and transparency; evidence of tool modification to great effect (beta testing); combines aspects of different tools into one; members not consciously aware that they are using a particular tool, or what its name is; you do some of those things automatically without necessarily naming tools while using it or implementing them according to the letter of the rule; don't follow a tool's 'user instructions' – I probably use tools more intuitively, I manage to pull things together in my head; I use tools quite flexibly; tool 'tweaking'; re-interpretation of Kanban to better suit firm's requirements; use many tools at a basic level
Company E Some tools are prescribed by the NPD process; some tools are extensively used because we know they work and they are part of our stage-gate process; everybody is part of a culture that is characterised by orderliness, structure and cooperation; some tools used with a longer-term view and benefits than just immediate outcomes; some tools used pro-actively; we have evolved a system including tools and have a good understanding of how it works for us; tools have become more sophisticated over time (e.g. roadmapping, EDMS); in the past it's been terrible but we've improved it to a point where it is easy to follow; we use a formal method for capturing user information and requirements; inflexible tools are eliminated; some tool usage is very prescriptive, allowing for almost no flexibility, while for others users have plenty of flexibility in how to use them; users sometimes refer to 'user manuals' when using infrequently-used tools; most tools have been refined to the firm's 'own version'; most of the things we do we are customising the way that we do it to best suit our needs, we massage and manipulate it; we adapted it, made it pragmatic; tool modifications are not formally documented

*(coded extracts from NVivo and case summaries)

The small firms in this study largely view tools as a means to an end, so much so that they often are not aware that they are using tools - "we don't think about tools" (Participant B2); "but it [tool use] happens anyway as a matter of course" (Participant D2). Tools are seldom linked to the process - "it's more like we use a range of tools and basically use them across phases through development" (Participant C2). Practitioners often use tools or aspects of tools in combination to achieve a particular outcome, as Participant D3 explains: "I don't really use formal tools for doing that [scoping new product briefs]. I mean I make notes all the time, I store specific emails in a specific place so I can go look back on them, that are ones relating to new product development. And I put thousands of hours of thought into it. And then I look at other factors like what's happening with energy use, what's happening with size of houses, size of rooms, what I think the regulators are gonna do, I look at an enormous number of factors and if they all fit together then I might put forward a proposition to say we should look at developing a [heating device] that's twelve foot wide. But I'm not convinced I could really claim to follow any specific process to do what I do, it's more done on just what conversations I manage to pull together in my head and intuitively know which is the right way to move forward."

In terms of flexibility of use, the five firms in the sample follow two main approaches that may overlap to some degree:

Low-flexibility tools

What can be considered standard tools of the trade e.g. 'CAD', 'prototyping', 'marketing plan', 'engineering document management system (EDMS)', 'feasibility studies', 'project management', 'design reviews', 'bug tracking', etc., are used in a way that Company E describes as "fairly focused, …, prescriptive of what we need to do, …, with those ones we have very little flexibility". These tools are often so closely linked to associated activities, that they become almost indistinguishable from the activities themselves, that their integration become automatic, used "in an unconscious manner" (Company A). Tools of this nature are normally used quite frequently throughout projects (having high diffusion among firm rates - see Figure 20, p. 113 and Figure 21, p. 114) and users tend to become very competent in their use, partly because they use it so often and because the system demands it from them. On average, these tools receive high thoroughness-of-use ratings (four or five out of a possible five), as is evident from both the case study findings and the survey findings (see Figure 22, p.

117). A common characteristic of these tools is their inherent structure that demands comprehensive use. For example, an entry into an 'EDMS' can only be done to a completion level of 100% or the system will not accept the entry, and a 'CAD' design on a particular piece of software follows very specific sets of steps from which the user cannot deviate. Linking these tools to stages in an NPD process is almost senseless (none of the firms in the study do it) as use of these tools becomes second nature for practitioners; their use simply becomes part of standard NPD routine that is not necessarily articulated on paper. The activities these tools are associated with, may however, be explicitly specified in the NPD process. Of interest is that practitioners predominantly use these tools in an interventionist mode (blueprints for action) and to a lesser degree in an analytic mode (problem solving) - refer to Section 2.6.6 p. 54 for a discussion of these concepts.

High-flexibility tools

The next broad grouping of tools, based on the level of flexibility of use, includes tools such as 'value added engineering', 'intellectual property management', 'post project review', 'lead user', 'teambuilding', 'design of experiment', 'roadmapping', 'focus groups', 'fault tree analysis', 'scenario planning', 'product life cycle', 'DfX', 'Porter's Five Forces'. When using these tools, team members are free to use their own discretion and interpretations of tools to get the desired results - "we're very flexible so I don't particularly adhere to any sort of way of working with these tools" (Participant A2). An example of flexibility of use is Company A that often tries different approaches in leveraging some of the tools at their disposal to get a job done. They describe how they used 'business planning' (a tool normally used in the dynamic mode - Section 2.6.6 p. 54) for creatively structuring communication among members (in a facilitative mode instead). In this example, they used business planning only for its apparent ability to put everybody on the same foot, and not for the conventional purposes of a business plan (for detailed discussion see p. 152). Practitioners generally hold tool flexibility in high regard. They believe custom-designed tools are often more flexible than off-the-shelf tools (Company E) and almost demand it from the tools they use.

Apart from high flexibility of use, several other factors distinguish this approach to using tools from the first. For a start, tools in this category are mostly called upon when specific circumstances demand it (hence they are predominantly being used in analytic, dynamic and facilitative modes); they are generally less thoroughly used than the first category (again referring to Figure 22, p. 117); relative to the first grouping they have lower diffusion among firm rates (see Figure 20, p. 113 and Figure 21, p. 114 of the survey findings). Although some of the characteristics of tool application summarised in Table 36 hold true for both approaches to using tools, it is particularly relevant to the second scenario, as is the focus of the discussion that follows.

Thoroughness of use

Practitioners in this study like using tools that are intuitive to use and that do not require the use of an instruction manual - "we throw away the tool book" (Participant B1). When applying tools, they tend to rely on their own interpretation of how a tool should be used – "we didn't go out and read out how you should use these tools", "[the way we apply tools] is far more intuitive, absolutely" (Participant C1); "although we're not experts in these tools we know how to intuitively use them, to a certain degree" (Participant C2); "I manage to pull things together in my head and intuitively know what is the right way to move forward" (Participant D3). In fact, the word 'intuitive' appears 14 times in the 17 transcripts of the interviews I carried out, which is an indication of how important practitioners view this aspect of tool usage.

Practitioners often use tools in a limited way - "[tools are] often not used to their full potential" (Participant A1) or poorly implemented (Company D). Many a time teams would use a tool no more thoroughly than what the situation requires, and once a desired outcome is achieved, would stop using the tool - "we focus on solving immediate problems, nothing more, nothing less" (Company B). The combined cases actually reveal several different reasons why tools are not utilised to their full potential, as summarised in Table 37 that also provides a breakdown for each company. As can be seen from the low-thoroughness counts in this table, there are many instances where tools are not thoroughly used, which automatically invokes a negative emotion as a first reaction. However, several of these reasons arguably appear to be quite legitimate ones, thus making practical sense why a specific tool in a particular situation should not be used in the most thorough manner. Such reasons include 1) using a tool until the problem is solved (partial usage may already have succeeded in solving the problem); 2) the nature of the task or problem at hand does not justify more thorough use; 3) being pragmatic in using tools to a level that they provide sufficient value; and 4) making trade-offs with other critical NPD factors, for example, saving development time by taking shortcuts in the way a tool is supposed to be used (eliminating seemingly 'unnecessary' steps). These are all examples of disposition-behaviour causal relationships (Cooper & Schindler, 2008).

Table 37: Reasons for not using some tools thoroughly

Company A (Low-thoroughness count: 16 ratings of 2 and below out of 5) Heavy workload – insufficient time; haphazard fashion in which tools were introduced – not everybody bought into a tool equally; some people were more resistant to change than others; lack of team maturity and discipline (new graduates)
Company B (Low-thoroughness count: 20 ratings of 2 and below out of 5) Only used until problem is solved; the nature of the task or problem at hand did not justify more thorough use; small team size – members must multi-task, rely on a very few people to get the job done; PM must wear many different hats; Immense time pressures and constraints – looming deadlines; some tools not perceived to provide billable output (despite adding value in a different sense)
Company C (Low-thoroughness count: 5 ratings of 2 and below out of 5) Severe time pressures; individuals fulfill multiple roles; it's because we don't have experts in all areas
Company D (Low-thoroughness count: 31 ratings of 2 and below out of 5) Some tools are perceived not to be of much value; users not at a level of development where they can use tools effectively; current levels of use are already reaping considerable rewards; poor exposure of people to development tools; some tools are also more relevant than others; inability of small firms to provide good opportunities for staff development in tool use
Company E (Low-thoroughness count: 19 ratings of 2 and below out of 5) Negative attitudes among individual team members liken some tools to fads - for many years we were quite successful without doing any of that, so why do we do this?; some tools are perceived to have little value; time constraints; extracting from a tool just the right level of information which is required by a particular situation; it's being pragmatic in using tools to a level that they provide sufficient value; some situations justify shortcuts being taken on tools; trade-off situations with other priorities

The remaining reasons why some tools are sometimes not thoroughly used definitely carry a negative connotation, suggesting imperfections in the system and the desire to improve: "But don't get me wrong, often I wish we could do it more thoroughly because I think we should be resourcing ourselves better so that we can do some of these things more thoroughly. So it's not as if I am satisfied with the degree to which we use all these tools" (Participant B2); "And I realised that sometimes, ..., if you actually used the tool more thoroughly we would get more value" (Participant E1). A similar pattern of reasons for superficial tool usage emerges among the sample firms:

- Small and often inexperienced teams carrying the huge burden of having to take care of a multitude of diverse activities and responsibilities;
- Looming deadlines and not having enough time to do everything;

- A general disregard for some tools, perceiving them as not useful, or just fads;
- The casual way in which tool adoption and use is approached (at least for certain categories of tools);
- Users being incompetent in the use of certain tools, not having received sufficient training.

Conversely Table 38 suggests reasons why some tools are used to a high degree of thoroughness (tools such as ‘prototyping’, ‘computer aided design’, ‘design review meetings’, ‘competitor analysis’, ‘concept testing’, etc.) Several of these reasons stem from a higher level of authority than the individual user - internal or external to the firm - that explicitly dictates or demands a high level of execution of certain tools.

Table 38: Reasons for using some tools thoroughly

Company A (thoroughness count: 63 ratings of 3 and above out of 5) If the person who introduced the tool had lots of ‘clout’; because the PM insisted on it; external pressure to comply with certain tool use procedures; if there would be possible repercussions if not used thoroughly
Company B (thoroughness count: 39 ratings of 3 and above out of 5) Some tools are integrated into strong quality culture; staff adhere to company’s 5 principles in everything they do
Company C (thoroughness count: 50 ratings of 3 and above out of 5) Industry regulatory and compliance factors
Company D (thoroughness count: 41 ratings of 3 and above out of 5) Certain tools like EDMS etc. – we need to rigidly stick to the form that we’ve decided, so they are pretty much policed and enforced with regards to how they are implemented; some tools are perceived to be able to provide more benefits than others; specific training provided for some thoroughly-used tools
Company E (thoroughness count: 102 ratings of 3 and above out of 5) Pressure and expectation from the core team; strong organisational culture that demands quality workmanship; some tools are extensively used because we know they work and they are part of our stage-gate process; some tools such as CAD are so inseparably integrated with activities and crucial to success; in-depth training provided for some tools; tool user groups encourage best-practice tool use; from a theoretical point of view it’s always best to get the most out of a tool

Another imposing factor that is more subtle in its demand for thorough implementation is organisational culture that includes company standards and team expectations, which results in peer pressure being exerted on the individual user. The last reason is perhaps the most powerful, best expressed by Participant E1: “Some tools are extensively used because we know they work”. This situation comes from experience and the conviction to use a tool thoroughly resides within the individual user. A user with this sort of conviction needs no external motivation to do what they have to do; they will use a tool to the best of their ability because they know that it is in the best interest of the project, and thus the firm.

Tool adaptation

This section addresses the issue of tool adaptation, which consists of a number of closely related variants, some of which I describe in Section 2.6.6 (p. 54) of the Literature Review. There is no doubt that, among the sample of firms, tool adaptations are commonplace. Tool adaptations typically occur in two types of situations. The first situation occurs before a new tool that is significant in scope, is commissioned for general use (see Section 7.1 p. 200), e.g. Company A's 'TRAC' tool, and the purpose is to eliminate some identified and known weaknesses in the tool through implementing some sort of improvement. The second occurrence of tool adaptation is during everyday operations when a user draws upon a particular tool of less significant scope, perhaps for the first time or maybe an infrequently used tool, to assist with some activity. Unless it is impossible to modify (e.g. 'CAD'), most acquired tools are adapted in some way. From the case study data, I am able to distinguish among four types of adaptations.

The first type of adaptation is tool customisation - "customising tools are fairly important, you've got to be able to kind of sometimes fit a square peg in a square hole, but all you got is a round tool, and you've got to shape it a bit so it fits in that square hole" (Participant A3). Thus, customisation means changing a tool so it becomes more suitable or appropriate to a particular contingency. Once a particular tool has been customised for a particular contingency, it may not be as appropriate for another. An example of tool customisation is TQM at Company B: "We're just looking at 'TQM', we don't follow a prescription, we absolutely adapt it to suit..." (Participant B2).

A second type of adaptation is the re-interpretation of tools, which happens very often with less comprehensive, infrequently used tools. In situations like these, users either 1) adopt a tool with which they are vaguely familiar for a particular purpose and use it in a manner that they think it was meant to be used in, or 2) consciously decide to use only aspects of a tool. An example of a tool in the first scenario is 'brainstorming'. Although the tool in its original form consists of a number of carefully crafted sequential steps, most users of this tool do not follow this sequence rigorously. Instead, they unintentionally alter the sequence of steps or omit some steps or principles altogether - "we have meetings with lots of people and a whiteboard, so we don't call it brainstorming, but that's really what it is" (Participant D3). Yet another example, this time from Company E: “Design of experiments, basically as I said, we don’t necessarily follow to the letter the strict protocol but we do our own design of experiments” (Participant E2). An example of a tool in the second scenario is Company E’s development of a marketing plan - “I don’t know if there is a right way of doing that, everyone has their own templates and things and we’ve got our own templates and I sort of used my own in that regard” (Participant E5). A second example is the way in which Company B reinterpreted the ‘Kanban’ tool, purposely omitting steps in the original ‘Kanban’, with great effect. A final example also from Company E: “Risk analysis was an example where we used a sort of a fairly formal risk assessment and management process, with a quite extensive matrix and all that, which just got too hard. We adapted it, we made it pragmatic, run by a Kiwi bloke who just couldn’t be bothered with all of this complicated stuff. And it worked really well” (Participant E1).

A third type of adaptation is tool modification, a process where some minor improvements are made to an existing tool. The improvement could be the addition of an extra feature, or extending functionality in one or more areas. Participant D3 explains how they modified the regulatory approval part of their NPD process by instigating a pre-test evaluation step where an early prototype is sent to England for initial feedback purposes so they can affect changes early in the design stage and thus potentially avoid costly corrections at the time of the formal approval process. When ongoing modifications occur over time, a tool is said to evolve - “if I look at the original product ‘road map’, it’s quite sparse, but now it’s actually quite in-depth as far as how we present it” (Participant E5); “We did not have an official ‘EDMS’ system, we do our own version of it and I guess we have been refining that each time we do a new project” (Participant E2). Tool evolution appears to be an ongoing process, as Participant E5 observes a general trend in Company E where tools are becoming more sophisticated - “In the past it’s been terrible but we have improved it to a point where it’s easy to follow” (Participant E2).

The fourth and final type of tool adaptation is known as tool reinvention or the intelligent reconstruction of tools. This happens when a tool is re-designed from scratch because of dissatisfaction with aspects of it, but in the process borrowing familiar concepts and principles from other tools - “I think that we’ve kind of just stolen the principles of these things [tools such as ‘theory of constraints’ and ‘lean manufacturing’] and if it makes sense we run with it. So we haven’t gone according to certain rules or certain procedures” (Participant B2).

Similarities and differences in tool application between small and larger firms

The observed tool phenomena regarding flexibility of use, thoroughness of use and adaptation that I discussed above, hold true equally well for the four small firms (companies A to D) and the larger reference firm, Company E. The only noticeable differences are:

- The NPD team in Company E has more experience and appears to be more mature than the other teams. Most of the core members and the extended team have been involved in several NPD projects before the current one. Their NPD process has been in place for many years and approximately 95% of the tools used in the project under review were internalised into a well-developed system before project launch. Because of this, they can confidently say that they use some tools extensively because they know they work. This combined confidence is not evident among the inexperienced teams in the smaller firms.
- Because of Company E's long-established culture of quality workmanship, its impact on how individuals use tools could be stronger than in the newly established smaller firms where cultures are still developing.
- Evidence of pro-active tool use and a bigger-picture view of projects is stronger among Company E's team members than elsewhere. This is another indication of team maturity that reflects concern for the longer-term wellbeing of the firm.
- Because of its size and greater access to resources, Company E is the only firm among the five in this study that provides formal tool training itself. This has a positive impact on tool familiarity among users and, as the empirical evidence shows (see Section 7.3 p. 211), there is a positive correlation between tool familiarity and thoroughness of use.

7.6 TOOL EXPERIENCES

The survey-part of this research identified patterns of tool satisfaction among a range of tools and studied the relation of tool satisfaction with thoroughness of use. In this section, I delve into the underlying factors of tool use that contribute to users' satisfaction or dissatisfaction with tools. I base my analysis on the assumption that users are satisfied with tools that succeed in providing a significant net value, and dissatisfied with tools that provide marginally or negative net value.

Factors contributing towards tool satisfaction

- Tool use that results in efficiency gains is highly valued, as Participant A3 attests: "Automation is a huge thing in our business"; "we are not shy of putting in a lot of work to put in something that would automate the management of a particular development project"; "once it's in [an automated tool], no matter how complex it is, then it is continuously providing value with very little input on our end, we just have to follow some basic process". The tool referred to here is 'TRAC', an automated online tool that creates a directory structure, a Wiki, a repository and a complete ticketing system for each new project.
- Flexibility of use is an important tool characteristic. Section 7.5 p. 224 provides ample examples to support this statement.
- The importance of a tool's perceived user-friendliness is clear from many participant references. In more specific terms, users like tools that are intuitive to use, that do not require too much training or having to refer to user manuals. In the words of Participant E3: "I like to think of a tool that I can use without reading the manual because I'm a real bloke you see and if you don't use it often that is a trap you fall into".
- There are numerous examples across the five cases that support the inclination and preference of users to be able to adapt tools for various reasons and in ways described in Section 7.5 p. 224.
- Tools "that succeed in creating a common language among team members and serving as a common platform that provides a systematic way for functioning and working as a team" are considered very useful (Participant C2). An example would be the way Company A uses business planning - "it puts everyone on the same foot" (Participant A3).
- Users are aware that most tools have different dimensions of complexity, which means that tools can be used at a superficial level or at a very substantial level, or anywhere in between. They also realise that they may not always be "at that stage yet [where tools can be used thoroughly]" (Participant D2), perhaps because of a lack of experience or training. Consequently, they look favourably upon tools such as 'time studies' and 'material flow' that can be used at a basic level yet provide them with considerable rewards (Company D).

Factors contributing towards tool dissatisfaction

- It is possible for a tool to be considered by some users as useful, while others in the same team may despise it, as the following example demonstrates. The commissioning of Company A's 'TRAC' tool involved a considerable amount of customisation that created a lot of teething problems causing plenty of unhappiness among team members, so much so that some terminated their employment. Once the tool problems were sorted out, everybody was able to appreciate its value in terms of time savings and the elimination of arduous tasks, but even so, the unpleasant experience left a bad taste in many people's minds and there are still some today who are skeptical about its usefulness.
- It is possible for tool users in one firm to be very dissatisfied with a particular tool, while users in another firm may sing its praises. The reason for this apparent paradox is that different users can interpret the same conceptual tool in many different ways. I use Company B's example of an 'ERP' system to explain what I mean. Their current 'ERP' system is a manual one that requires a huge time commitment for its successful implementation - "I'm forever trying to chase information and we're doubly entering data and everyone's entering the same thing, at different stages" (Participant B1). Users at another firm may have access to a sophisticated 'ERP' software package that does not cause the quoted frustrations among its users. Company C uses a software versioning tool, which Participant C3 describes as "not a particularly elegant solution" and "far from ideal", because of its interface and a lack of certain functionality. Clearly, the level of sophistication of a tool can be a major source of satisfaction or dissatisfaction for users.
- Users may find some tools useful, but at the same time not be satisfied with them. One example is Company A's experience with 'MS project'. Although use of this software succeeded in keeping the project on track, the ongoing effort required to manage it on a frequent basis was eventually too much, and the tool was abandoned - "we tried it, we gave it a good crack to see if it actually gave us value…, but found it didn't" (Participant A3, Section 6.1.6). The tool's return on investment was not sufficient to justify its ongoing use. In this context, investment refers to effort and time, not money. Another example is Company C that uses their "own little system which is on Excel which is not very successful" (Participant C1) to manage their inventory, while inventory management systems of varying sophistication levels exist elsewhere.

- Situations may occur where users' failure to use a tool in the way it was designed or supposed to be used, causes dissatisfaction with the tool. Participant B rates his company's NPD process low in terms of usefulness as members in the core and extended teams often do not obey the principles of this tool, thus "creating a lot of mayhem out there". He describes an incident where the design function introduced a new type of assembly without informing other functions on time because of a failure to observe the rules of the NPD process. It is clear that a lack of discipline in a tool's implementation may [unfairly] lead to dissatisfaction with the tool.
- Participant D3 comments that tools' limitations are not always clearly understood and that users may be misled as a result. To prove his point he tells the story of how his use of 'focus groups' failed to provide him with the correct information on what customers really want in a heating device (see Section 6.3.6 p. 173 for a detailed explanation). Had he not realised the limitations of this tool, he would have ended up with the wrong product brief.

8 CONCLUSIONS AND IMPLICATIONS

The purpose of this chapter is to provide a general conclusion to the thesis's research questions and hypotheses, and to summarise its implications for theory and practice.

This chapter is broadly split into four sections. The first section provides a direct answer to the primary research question by integrating the findings of the survey (Chapter 5) and case study (Chapter 6 and 7) research. In doing so, I try to follow a sequential structure according to the eight research questions (Section 1.4, p. 4), and where relevant, addressing the conclusions regarding each hypothesis. This section also provides an overview of the contributions and conclusions of this thesis. The second and third sections present the implications of these conclusions in relation to theory and practice. Finally, the fourth section provides directions for future research.

8.1 CONCLUSIONS REGARDING THE RESEARCH PROBLEM

> *"How can small high technology firms better select and use NPD tools in developing new products more effectively and efficiently?"*

Prior to providing a general conclusion to the thesis's research questions, I first report on the survey findings of the prevailing conditions regarding NPD process (section 8.1.1) and innovation strategy (section 8.2.2), as an understanding of these moderating variables inform the interpretation of the sections that follow.

8.1.1 NPD Process

I include my investigation of NPD process as part of this study for two reasons. Firstly, because a study of NPD tools without understanding its relation to process and related activities, is incomplete. As such, it provides an important backdrop against which tools can be studied within the broad context of a project that follows a certain process to reach completion. Secondly, I consider the NPD process as an important tool in itself, as I explain in detail in Section 2.2.3 (p. 15).

Overall, smaller firms in this study are far less formalised and structured than larger North American, Swedish and Malaysian firms in their approach to NPD. This findings supports past research among SMEs that found they do not innovate in formally recognised ways (Hoffman, et al., 1998); they often lack structure (Maravelakis, et al., 2006); and they conduct NPD in an ad hoc manner (Millward & Lewis, 2005). This finding is even more remarkable when considering another study by Kleinschmidt (1994) that found that European firms followed a considerably more formal approach to NPD than North American firms. Despite the fact that most ‘best-practice’ companies in the world have implemented a robust idea-to-launch system such as ‘stage-gate’ (Cooper, Edgett, & Kleinschmidt, 2002; Griffin, 1997b), a mere 30% of participating firms in this study indicate the use of stage-gates in their NPD processes, while only about 20% indicate that they do have formalised, documented processes in place. Closely associated with informal process is poor structure, or low levels of NPD process sophistication. This finding supports the view of the World Economic Forum expressed in the Annual Global Competitiveness ranking (Schwab, 2009) that a lack of business sophistication and innovation is holding New Zealand (in this instance) back from becoming an advanced economy. The same may be true for small high technology firms in other countries.

Despite a general lack of formalised process among my sample firms, I find that when present, it correlates positively with improved performance in all measures of NPD success (accepting the hypothesis $H1^{perf}$). This finding closes a previous gap in the literature as expressed by Ledwith and O’Dwyer (2008) that no studies were found that linked NPD process formality with new product success in small firms. Not only does the mere presence of process appear to have a positive impact, but also the level of sophistication to which these processes are developed (accepting the hypothesis $H2^{perf}$). The implication is that those firms that do not yet have processes in place (approximately 80% of small firms indicated they do not have formalised documented processes), should consider introducing some form of standardised approach to product development. Those firms that already have a basic structured process can expect to get better results from a more sophisticated gated process executed by cross-functional teams. Although this study stops short of measuring how well firms perform their processes, by synthesising my findings with past research, I suggest that low process proficiency could be the reason why even firms with sophisticated processes fail to show significant performance gains in product outcomes. If so, firms should both introduce better formal processes and strive to be more proficient in their execution of these processes. Together, these actions could produce better NPD outcomes in terms of both process and process outcome (product).

My findings furthermore indicate that more formalisation and better structure with regard to process are directly and significantly associated with higher levels of tool adoption/application in projects (rejecting the null hypothesis $H3^{adopt}$). While teams should never adopt tools simply for the sake of ‘being seen to be doing the right thing’, as the negative ‘Cargo Cult’ experience of Case A demonstrates, I found statistical support suggesting that most tools have the potential to significantly improve performance in specific areas of NPD (mostly rejecting the null hypothesis $H5xy^{perf}$) - see Table 21, p. 132 and Table 22, p. 133 - especially when used at more substantial, rather than superficial, levels of thoroughness (mostly rejecting the null hypothesis $H4^{perf}$). Thus better process, in conjunction with sufficient levels of process proficiency and thoroughness of tool use, hold the promise of better performance. This finding supports that of Rigby (2001b) who found significant differences between successful and less-successful companies in their ability to use tools.

Despite the empirical support for more process formalisation, Seely Brown and Duguid (2000, p. 73) caution practitioners that “top-down processes designed to institutionalize new ideas can have a chilling effect on creativity”. They found that in practice, too much inclination towards process in an effort to improve efficiencies may provide lots of structure, but at the same time “could easily destroy important patterns of activity that lie outside the domain of formal processes” (Knott, 2006, p. 1092). The authors suggest it is commonplace in organisations of all sizes to have a tension between the way matters are formally organised (process) and the way things actually are done (practice). Key to success is finding the right balance between formality and improvisation - “practical inventiveness to get around the limits of process” (Seely Brown & Duguid, 2000, p. 75) - as ultimately both are integral components of a company’s best practice.

8.1.2 Innovation Strategy

Based on my definition of NPD tools in Section 2.2.2 (p. 15), I studied ‘innovation strategy’ as a tool even though it is one that is normally implemented at the enterprise level. I provided justification for including some enterprise-level tools in the ‘notes section’ below Table 1 (p. 19). As such, this study is the first, amongst firms of any size, to test the relationship between innovation strategy and the various NPD performance measures at the project level. My results suggest that being guided by an innovation strategy is likely to improve performance measures at least marginally in all areas, but significantly so with regard to launching on time and improving cooperation between cross-functional team members (accepting the hypothesis $H3^{perf}$). Only one third of the firms in my study are guided by formal innovation strategies. This finding underwrites that of past research among SMEs suggesting that NPD strategy tends to be implemented with minimum formalisation (Lindman, 2002). Because of the small size of New Zealand firms, managers may discount the value of and need for strategising their NPD efforts, but as the results suggest, should take notice of the potential gains.

8.1.3 Tool Adoption

RQ1: To what extent do practitioners adopt and use tools or categories of tools in their NPD projects? (What are the patterns of tool adoption?)

Using cluster analysis, I was able to identify three different groups or clusters of firms based on their overall level of NPD tool adoption. These are high, moderate and low tool users, each roughly representing 45%, 20% and 35% respectively of the firms partaking in the study. This finding corresponds pretty well with Maylor's (2001) 21-tool study of 46 larger firms in the Midlands and South of England (corresponding values of 48%, 22% and 30%), which provides some support for external validity of my data set. The average tool penetration rate for small high technology firms is 31.3%, a value that corresponds very well with Nijssen and Lieshout's (1995) corresponding 30% that they obtained 15 years earlier in their 11-tool study of 75 industrial Dutch companies (median size of 200-500 employees). Comparing my findings, cluster for cluster with Maylor's, I find that the average diffusion rates of small firms are 20 to 25 percentage points lower than those of larger firms by. Given the time differences between my study and the two studies cited above, it seems reasonable to postulate that currently, on average, small firms use fewer tools in their NPD projects than larger firms elsewhere. Current levels of tool adoption in small firms are probably around 1990 - 1995 levels in Europe and perhaps the USA.

Contrary to expectation, I established that by simply adding more tools to its arsenal - as reflected in the three tool-use clusters - a firm may not improve its NPD performance significantly (accepting the null hypothesis $H6^{perf}$). Rigby's (2001b) study of management tools also found no correlation between the number of tools used and overall company success (he found that the average number of management tools used by successful and less successful companies is the same). My findings indicate no significant performance differences between high, moderate and low users of tools. The most apparent reasons for this are that not all tools necessarily translate into improved NPD performance, and those that do, do so to differing degrees. I discuss this further in Section 8.1.9.

My investigation to determine whether individual tools belong to unique clusters found no evidence in support (accepting the null hypothesis $H4^{adopt}$). I also found that firms belonging to each of the three clusters engage tools in the 12 categories proportionally. In other words, I could find no evidence to suggest that firms in the high-use cluster favour any category of tools, for example engineering and design tools, more so than information management tools. As these findings indicate, apart from the actual number of tools adopted by firms in the three clusters, the patterns of tool adoption are very similar across high, moderate and low tool users.

Contrary to expectation, and similar to larger firms (Tidd & Bodley, 2002), NPD teams in smaller firms do not appear to adopt a greater number of tools in projects of a more radical nature than they do in incremental innovation type projects (accepting the null hypothesis $H1^{adopt}$). Instead, as stated before, it appears to be the sophistication level of the governing NPD process that dictates the number of tools a team is likely to adopt over the course of a project. The empirical evidence suggests that NPD teams that follow more elaborate or sophisticated processes are likely to use more tools than teams with less formal approaches to NPD (rejecting the null hypothesis $H3^{adopt}$). Contrary to expectation, I found no difference in the levels of tool adoption between industrial and consumer projects (accepting the null hypothesis $H2^{adopt}$).

Small firms appear to favour certain aspects of NPD, such as marketing and market research, creativity and problem solving, engineering and design, and manufacturing, over others. This observation confirms past research that SMEs place too much emphasis on technology issues at the expense of other management issues (Millward & Lewis, 2005). Important aspects of NPD such as team support, risk management, information management, general management, and learning and review, receive less attention relative to the others over the life cycle of an NPD project. Moreover, firms in this study generally do not match the uptake of tools in ways consistent to the importance they assign to the various aspects of NPD. One would expect NPD teams to use more tools in those areas that they deem most important, but the opposite seems true.

A comparison of the tools in Figure 20 (p. 113) and Figure 21 (p. 114) furthermore shows that small firms generally favour functional type tools to support tools. As product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm (Ulrich & Eppinger, 2008), the tendency to neglect important aspects of NPD may not be a weakness in the current small scale of projects, but it can quickly become one if projects get larger and firms grow bigger. For example, because of its small size, a team of five people may not feel the explicit need for team support, information management or learning and review as these activities are probably sufficiently taken care of in a non-labeled sense on a daily basis through close interaction and face-to-face communication among team members. Similarly, risk management and general management might have been covered at proportionate levels of depth despite not having expressed or addressed these issues formally.

Smaller firms appear to follow similar tool adoption patterns to larger firms for tools of a less complex nature. In a sense, Table 17 (p. 112) can be seen as a popularity chart as it clearly indicates which tools are most commonly used among small firms, and which least. When assimilating this information, it is important to keep Knott's (2008) caution in mind that the tools in list-based surveys do not accurately capture the tools and terminology practitioners are using as they may err on both sides of reality. He argued that 1) tools that practitioners use are often different from those highlighted by tool surveys; 2) some tools have overlapping content; and 3) tool use quantification is problematic as tools are often absorbed into practice and cease to be visible as tools. I found supporting examples in this study: "we have meetings with lots of people and a whiteboard, so we don't call it brainstorming, but that's really what it is" (Interviewee D3); "yeah we've used it" (Participant B1's comment when completing the survey). Obviously, practitioners may 1) have indicated tool usage in some cases even though in reality they may only have used aspects of a tool, or 2) consider what they did as using a tool while under my operational definition of tools they did not (e.g. Company B's scenario planning - "I use it all the time in my head"), or 3) have failed to indicate tool use because they did not recognise it as such.

For more elaborate or advanced tools, such as 'TRIZ', 'morphological analysis', 'fault-tree-analysis', 'conjoint analysis', 'design for six sigma', small firms appear to have much lower adoption levels than larger firms. This is probably due to the more prevalent constraints on small firms regarding access to specialists in these areas and the lack of sufficient funding and time to engage in the use of these tools.

While plenty of research has been done in uncovering tool adoption patterns and determining determinants of tool adoption in firms, surprisingly the process of adopting tools has received little attention. I found little reference to how firms should go about adopting tools into their organisations. A study of IT tools found that major corporations continue to adopt tools from the outside, or develop them internally in a piecemeal fashion rather than in an integrated manner (Farris, et al., 2003). This is normally done to profitably improve sub-processes over relatively short timescales, without realising that such situations often lead to overall lagging process flows in the longer term. I found the same piecemeal approach to adopting tools among the case study companies A to D, and I believe there is a very good reason why things happen this way. As I explained with the tool needs hierarchy in Section 7.4, start-up firms build up an arsenal of tools over time as they evolve and their needs develop. Most often it was impossible for team members to know in advance which tools were needed further down the line; knowledge of this only comes through experience. Especially during the first project, all the attention is directed to the product and tools are merely incidental to the activity of creating a product. So, unless a very experienced NPD team or individuals are recruited into a start-up business so they know from the offset what to expect and what to plan for, it is unlikely that the piecemeal approach can be totally avoided.

The lack of tool adoption process that I observed in my study prompted me to piece together empirical evidence from my case study participants to obtain a broad picture of how things are currently done by default within these firms (see Figure 35, p. 201). The last phase in this process, Phase 9, is called Internalisation. I borrowed this concept from Whittington (2006) who introduced it for strategy tools within organisations, describing how tools are linked to firms' operating procedures and cultures. Through my case study analysis, I was able to identify two additional potential link mechanisms that specifically apply to NPD tool internalisation in companies. They are the NPD process itself, and the phenomenon where tools reside with individual team members. This study led me to be the first to define NPD tool internalisation as the various mechanisms through which an organisation integrates both acquired and internally developed tools for use by practitioners. I consider this an important contribution to both theory and practice for two reasons. Firstly, it draws attention, for the first time, to four tool adoption mechanisms that may through future research lead to explanations why some tools or groupings of tools are used differently from others. I am referring to differences such as thoroughness of use, flexibility in use and interpretability of tools. Secondly, awareness and understanding of these mechanisms may help managers do a better job managing the tool adoption process, thus indirectly improving the management of innovation within their organisations. More specifically, this aspect refers back to the innovation management activity area of 'using innovation tools appropriately' under the controlling function in Figure 6, p. 35. My assessment of the current situation is that the tool adoption process appears to be very badly managed within the case study firms, and it becomes a challenge for future research to determine if better practice can be developed in this regard, using as a starting point my empirically observed phases in the tool adoption process. Thomke (2006) believed there is merit in better practice when he stressed the importance of correct deployment of tools in saying that what matters most is not the new tool per se, but how it is deployed within a particular situation. Company A learned this lesson the hard way in not doing it right with their 'TRAC' tool and eventually paid the price when several team members resigned because of unhappiness with the tool and the way it was internalised. Thomke further proposed that managers should first establish the connection between a new tool and the work that must be done, before proposing its use at a particular point in the innovation process. It is imperative for the innovation process to be designed first, followed by the right tools integrated with the work that needs to be done, not "unilaterally pasted onto existing routines or substituted for what is presumed to be an equivalent" (Thomke, 2006). Thomke's suggestions do make partial sense for tools that lend themselves to be 'pasted' onto existing processes and procedures, but as I have shown above, certain categories of tools may be better linked to, or internalised via, organisational culture, and through individuals.

8.1.4 Determinants of Tool Adoption

RQ2: What factors determine tool adoption?

Past research among larger firms has revealed several tool determinants, most of which tested insignificant for smaller firms (rejecting hypotheses $H1^{det}$, $H2^{det}$, $H3^{det}$, $H5^{det}$ and $H6b^{det}$). These respectively include the level of communication among departments, the prior use of tools, top management support, an NPD strategy focusing on turning out many new products, and firm size in terms of annual turnover. Factors that appear to be conducive to tool adoption among smaller firms were found to be the number of people involved in the project (accepting $H4^{det}$), firms size with regard to number of people employed (accepting $H6a^{det}$), the number of departments involved in the company's NPD (accepting $H7^{det}$), and the number of stages within the NPD process (accepting $H8^{det}$). As indicated earlier, and of further significance, is a well-defined NPD process. Therefore, firms wishing to create climates conducive to tool adoption, should firstly pay more attention to the way they organise NPD activities, and secondly, encourage engagement from as many people as possible – within and outside the firm.

8.1.5 Obstacles to Tool Adoption

RQ3: What are the major obstacles to tool adoption?

The questionnaire results where participants rated some common obstacles that were found to exist among larger firms, provided no surprises. Five out of seven listed obstacles achieved obstacles ratings over 40%, which deserve further commenting here. Similar to larger firms, a major obstacle to tool adoption among smaller firms is the associated time and monetary costs of tools. As my review of the NPD literature in small firms showed, small firms generally suffer from a greater lack of resources than large firms – financial and human – to keep innovating and broaden the product range. From my findings it appears that the acquisition of tools that are expensive to purchase or implement from a time perspective, puts an extra burden on small firms. The severity of this is further reflected in Participant B3's remark that making one costly mistake (purchasing a relatively expensive tool that turns out to be a failure) can easily jeopardise a whole project or even worse, put the whole company at risk. It is hard to imagine that a situation like this could have the same repercussions in bigger firms.

While the cost-obstacle of tools is a fundamental one that may prove to be a difficult barrier for small firms to overcome, the next 'cluster' of four significant obstacles resulting from the survey all relate to practitioners' attitudes and perceptions of tools. They are the questionable return on investment that tools provide, a lack of awareness of tools, an uncertainty regarding the value of tools, and a perception that tools are too difficult to implement. Clearly, managements are capable of addressing these problems by providing proper training. Unfortunately, as my earlier review of the literature also indicates (Section 2.4.2, p. 38), small firms do not provide sufficient training opportunity for employees in general, not to mention specific tool training. The lack of training in small firms is obviously an area of great concern.

My follow-up interviews with seventeen practitioners also did not reveal great new insights, but it did confirm various findings from previous research. For example, I found evidence where team members in Companies A and E resisted change (implementing a new tool) because they preferred the status quo, in line with Thomke's (2006) earlier findings. Another example is the 'Cargo Cult' phenomenon described by Company A, which is basically identical to Rigby's (1993) 'succession of management tools'. These terms describe rare situations where practitioners adopt large numbers of tools for all the wrong reasons, believing that tools will make them successful. As expected, users soon became disillusioned with such tools and developed a general dislike of tools, which then became a barrier to further tool adoption.

A final observation regarding obstacles to tool adoption is actually a theme that appears frequently throughout my thesis - the importance of structure. Both the survey and the case study findings confirm that more structure equates to more tools being adopted (a good example of triangulation of data), and of course the opposite - that lack of structure inhibits the adoption of tools.

8.1.6 Tool Awareness and Familiarity

RQ5: To what extent are practitioners familiar with the tools they use?

As I did not do a thorough investigation on tool recognition or awareness among practitioners as part of my survey study, I cannot categorically state whether the practitioners have good awareness levels of tools or not, or compare it to awareness levels elsewhere. Survey participants did indicate, however, that lack of awareness was indeed a major obstacle to tool adoption within projects (Figure 23, p. 119). From my limited observations when a handful of participants completed the questionnaires, and during the interviews, it did become apparent that practitioners in small firms are facing the same or perhaps an even bigger 'awareness problem' as elsewhere (Mahajan & Wind, 1992; Thia, et al., 2005), namely where they are uncertain about certain tools when given the names of tools only, but once they got an explanation, they felt more confident in their understanding of these tools (refer to Section 2.6.4, p. 50).

With regard to tool familiarity, the case study findings indicate that users in this study show relatively low to medium levels of tool familiarity for about 30% of the tools they already use, which leaves scope for improvement. Not having comparable benchmark data with larger firms, makes it difficult to assess whether the familiarity problem is bigger among practitioners in small firms than in large firms. Formal tool training in these small firms is generally nonexistent, hence it is up to individuals and project leaders to create opportunities for improving their skills in using these tools.

The quantitative findings of the case study research (Section 7.3 p. 211) indicate that tool familiarity is directly proportionate to thoroughness of tool use (rejecting null hypothesis $H2^{thor}$). By itself, this is not an unexpected result, as it makes sense that the more one is familiar with a tool, the more thoroughly one is likely to use it. Only when this finding is integrated with the earlier survey finding (Section 5.2.15 p. 141) that shows a positive correlation between thoroughness of tool use and NPD performance ($H4^{perf}$), that a more insightful observation becomes evident. For the first time, there is empirical evidence to suggest a series of links, not necessarily causal ones, between tool familiarity and thoroughness of use, and between thoroughness of use and overall NPD performance. I furthermore found a strong positive correlation between thoroughness of use and perceived usefulness of these tools (rejecting null hypothesis $H2^{useful}$). These findings indicate that the level of tool familiarity is indeed an important factor in tool usage that practitioners should take seriously.

To address the problems of a lack of tool awareness and low levels in tool familiarity, Nijssen and Frambach (2000) suggest companies get outside help from consultants or market research companies to gain familiarity with new tools, or even outsource specific tools prior to adoption. As suggested earlier, the need for and value of tool training cannot be underestimated.

8.1.7 Reasons for Tool Use

RQ6: Why do practitioners use tools?

A review of the literature (Section 2.6.5 p. 52) mainly pointed to efficiency and effectiveness as the main motivators for practitioners to adopt and use tools. The former predominantly involved the NPD process - e.g. reducing time-to-market and project cost, or eliminating redundant processes. Effectiveness motivators, it seems, can relate to both process - e.g. research the market, identify and solve problems, predict success - and product - e.g. reduce product cost, ensure product quality, meet target specifications. While knowledge of these factors may convince practitioners of the potential benefits of tool application and therefore motivate them to adopt tools, it serves very little purpose otherwise. Therefore, in my analysis (Section 7.4, p. 215) I went further by explaining, with the aid of an empirically derived tool needs hierarchy (Figure 38, p. 216), how users' tool needs evolve over time, starting with effectiveness tools, moving on to problem solving and efficiency tools, and eventually ending up with tools of a strategic nature that help with the productive use of resources. These are the underlying reasons why practitioners use tools.

8.1.8 Tool Usage

RQ7: How do practitioners apply tools in practice?

Tool usage is potentially a huge field of study. I focus most of my discussion here on three main areas of tool usage that emerged from my review of the literature: flexibility of use, thoroughness of use, and tool adaptation.

Flexibility of use

My case study findings among small firms support those of Nijssen and Frambach (2000) among larger firms that found that practitioners use, and like using, tools with a high degree of flexibility. However, close observation of my five participating firms revealed that practitioners might not be able to use a specific category of tools, which I refer to as low-flexibility tools, as flexibly as they do with other tools. There appears to be two main reasons for this. The first is where somebody or some entity in a position of authority demands or prescribes certain tools to be used in a specified and justified manner, and the second is where the inherent structure of the tool forces the user to use it in only one possible way. Despite their inability to use tools in this category in a flexible way, users do not seem to mind having to stick to the rules as they appreciate and understand the reasons why it is required. The fact that tools in this category typically have relatively high thoroughness-of-use and satisfaction ratings, are evidence of this. As long as users understand the merits of using a tool to the letter, they appear to be willing to comply, which is good news when considering the intuitive expectation that users may dislike tools associated with inflexible use.

A second category of tools, which I refer to as high-flexibility tools, allows users much more freedom of interpretation, greater levels of adaptation, and discretion in regards to what level of thoroughness a tool is to be used. Knowing the differences between low- and high flexibility tools adds another level of understanding in explaining why practitioners use tools the way they do. It can also be of value to process managers when designing new processes for forthcoming projects, or when redesigning existing processes. As past research shows (Section 2.4.1, p. 37), small firms generally function more flexibly than large firms do. It remains for future research to determine whether small firms also use tools in ways more flexible than large firms.

Thoroughness of Tool Use

In terms of thoroughness of tool use, a general observation from my survey findings indicates that most tools are not used to their full potential. In the survey, I explained thoroughness of use as the degree to which a user used aspects of a particular tool. On average, only three out of 76 tools achieve thoroughness ratings over 75%, while 55% achieve ratings between 50 and 75%, and a whopping 42% of tools achieve ratings lower than 50%. Tools that are more popular seem to be more thoroughly used than the less popular ones (a comparison of Figure 22, p. 117 with Figures 18 and 19, p. 113). Congruent with my earlier discussion on the low uptake of more sophisticated or advanced tools (the less popular tools in this study), it appears that tool users not only shy away from using the 'more difficult' tools in the first place, but also make less effort in using them to their full potential when they do use them. Contrary to expectation, I found that practitioners do not necessarily apply tools more thoroughly in the more complex projects (e.g. radical innovation projects) than in simpler projects (e.g. incremental innovation projects), thus accepting the null hypothesis $H1^{thor}$.

Apart from the above indication that tool popularity in terms of its diffusion among firms, at least to some degree, determines how thoroughly it might be used, the survey findings are not able to explain why some tools are used substantially, while others are only used superficially. It was only when I conducted the interviews, that I became aware why tool users may have both good reasons (what I refer to as legitimate reasons) and not-so-good reasons (referred to as reasons born from unfortunate circumstances) for justifying why they sometimes use tools superficially. This is an important finding as it challenges the intuitive notion that superficial tool usage is always a bad thing, especially when taking into account my earlier finding that thoroughness of tool use correlates positively and significantly with NPD performance measures. In summary, while for some tools thoroughness-of-use may be directly associated with improved NPD performance in some area/s, it seems very plausible that for other tools a lesser thoroughness-of-use-level may accrue benefits in ways that are not so easy to measure, e.g. allowing more time for carrying out activities that would otherwise not have been done, or engaging more tools than would have been the case otherwise. When executing projects, managers and practitioners need to constantly consider project and firm-specific factors when making thoroughness-of-use decisions, bearing in mind or even assessing the potential trade-offs between using a tool thoroughly as opposed to using it less thoroughly.

Tool adaptation

I found ample evidence among the case study participants that practitioners do exactly what Ulrich and Eppinger (2008) suggest - adapting tools to meet their own needs that reflect their institutional environments. While many others (Jarzabkowski & Wilson, 2006; Knott, 2008;

Lozeau, et al., 2002; Nijssen & Frambach, 1998) echo this sentiment, nobody actually explains the various manifestations of tool adaptation. Through a careful analysis of described adaptations by my case study participants, I was able to distinguish among four types of tool adaptations that are widely practiced among them all: customisation, re-interpretation, modification, and reinvention. Of the four, re-interpretation appears to be the one type of adaptation that is most frequently done, and mostly so within the context of a particular project. As such, it is a strong reflection of the actual interpretation and execution of tools, reminiscent of the concept of praxis that I defined in Section 3.1.2, p. 66.

In a sense, it is possible to draw a similarity between the way practitioners adapt tools and the practices of jazz musicians, an idea that I borrow from Barrett (1998). He observed that organisation theorists adopted Levi-Strauss' (1966) concepts of bricolage (the art of making use of whatever is at hand), and the bricoleur, to draw similarities between organisational practice, in particular those studying organisation as improvisation, and the practice of jazz musicians: "The bricoleur, like the jazz musician, examines and queries the raw materials available and entices some order, creating unique combinations through the process of working through the resources he/she finds" (Barrett, 1998, p. 615), and "members' capacity for bricolage and pragmatic reasoning, their ability to juxtapose, recombine, and reinterpret past materials to fashion novel responses." (Barrett, 1998, p. 619). In similar fashion, when faced with the need for tools, NPD practitioners take a pragmatic approach in identifying which tools are available and accessible in both the firm and external environments, and through the practices of customisation, re-interpretation, modification, and reinvention, 'fashion novel responses' that are unique to each enacted NPD process or project. The creation from the bricolage process then becomes part of the stock of routines/practices for that individual, group or organisation.

It is important to understand the subtle, but distinct, differences among these adaptations, as it may result in more effective tool application if users are aware of the various options available to them for getting the best results. Closely associated with re-interpretation is what users describe as the ability to use tools intuitively - a practice held in high regard. These distinctions in tool adaptation could also be of value to tool developers, encouraging them to develop tools that users can not only customise, re-interpret, or modify according to their specific needs, but which are also very intuitive to use. Clearly the community of practice has the biggest influence on how tools are enacted - more so than 'instruction manuals' or the protestations of academics presenting 'proper' use of particular tools.

Participant comments such as ‘with great effect’ and ‘it worked really well’ indicate that users generally have great success with tools that they adapt. Adaptation is not always easy, however, as company A’s experience with their TRAC tool is a testimony of. Despite some difficulties, they persisted and eventually succeeded in modifying and customising a tool that is proving to be very successful.

The overwhelming support for tool adaptation by both academics (literature review) and practitioners in my study, makes another strong argument against the concept of ‘best practice’ which I discussed in Section 3.1.1, p. 65. Best practice would suggest a standard approach to using a particular tool, irrespective of the particular contingency, while the term ‘effective practice’ is more conducive to tool adaptation for better meeting specific needs. This view is supported and expressed by many others (Cormican & O'Sullivan, 2004; Kahn, et al., 2006): that so-called ‘best practice’ is context specific and that companies need to adapt it [tools] to specific environments and circumstances.

8.1.9 Tool Impact on NPD Performance

RQ4: Does the use of NPD tools relate to NPD performance?

In my literature review, I express the frustration of not being able to find significant or suitable benchmark data on the impact of tools on NPD performance for making appropriate comparisons with other contingencies. With this study, I took the lead, at least with regard to smaller NPD firms, in establishing a performance reference dataset for six types of NPD project strategies and a broad selection of NPD tools. I also established the relationships among a variety of independent variables related to tool use, and twelve dependent variables of NPD performance.

In the following sections I reflect on the main contributions of my performance studies.

NPD project performance

NPD firms typically execute projects that fall within six possible NPD project strategies that result in cost reductions, repositionings, incremental improvements, additions to existing lines, new-to-the-firm products, or new-to-the-world products (Booz, et al., 1982). Although not the primary aim of my study, it is the first of its kind to assess the relative success of these different NPD strategies, using 12 different performance measures, among a sample of 99 New Zealand firms, as proposed by Griffin and Page (1996). This work is of significance to the current study of NPD tools for two reasons. Firstly, it provides useful insights into how the distribution of firms in my sample (Figure 11, p. 82) is performing with regard to project strategy, and secondly these findings provide more meaningful context against which tool performance attributes can be compared.

The 12 performance measures that I used in this study can broadly be divided into two groups: process and product (project outcome) performance. On average, none of the 12 performance ratings (see Figure 27, p. 124) scores above 80%, which implies that the respondents in the sample firms do not believe they have achieved excellence in any particular aspect of NPD. Interestingly though, on the same perceptual scale the seven product performance measures are, with the exception of the profit measure, all outperforming the five process measures. The significance of this is further reflected in the fact that on average, product performance measures outperform process measures by almost 20%. It is not difficult to explain this, as both my survey and case research provide ample evidence that indicate a general preoccupation among small firms with 'state-of-the-product' matters while process and structure are being neglected.

Contrary to expectation, my findings indicate that project strategies of a more innovative nature generally outperform strategies of an incremental nature. In saying this, I acknowledge small sample sizes for some of the strategy categories, which may affect the external validity of this particular observation. A possible explanation for this may be that NPD teams tend to put more effort into projects of a more innovative nature as these projects presumably present more challenges, and are more interesting than cost reductions and incremental improvements. When comparing different performance across project strategies, it is of great concern to see that none of the project strategies resulted in satisfactory profit margins. The findings furthermore indicate relatively poorer performance in measures of NPD process quality than in measures of product outcomes.

Tool and tool-related factors having an impact on NPD performance

As I have discussed the details elsewhere, I only provide a summary of the main contributions here.

- NPD process sophistication is directly correlated with process performance, but not with product performance. The first part of this finding makes good sense, as one would intuitively suspect sophisticated process to be associated with improved process performance. I explain the insignificant tests by saying that when it comes to product performance, what affects the outcomes is not the presence of a process per se, but how well the process is executed. My evidence is indicative of low NPD process proficiency levels among small firms.

- A simple visual inspection of survey data (Figure 30, p. 129) shows that those firms with innovation strategies marginally, but consistently outperform those without them. The fact that two performance outcomes tested statistically significant at the 95% level gives further merit to this finding and suggests further research to test this relationship in greater detail.
- My findings show that 60% of tools in this study have significant impacts on at least one of the 12 performance areas of NPD. The significant associations between individual tools and performance areas in Table 21 (p. 132) and Table 22 (p. 133) provide useful guidance for tool selection when the objective is to enhance performance in a specific area or areas of NPD performance, or to improve the overall performance of a particular project strategy.
- Certain tools, such as 'computer-aided engineering' and 'design for six sigma', may actually have a negative impact on certain performance areas, such as product sales and profits. This evidence supports Maylor's (2001) theory that some tools may have significant adverse effects in certain areas of NPD performance. This phenomenon of adverse effect is to be expected, as it is not difficult to conceive how a tool such as 'configuration management system', for example, can improve NPD performance in several areas such as 'speed to market', 'launched on time', and 'degree of external collaboration', yet at the same time have a negative impact on the product's profitability because of its associated costs. In more general terms, a hypothetical tool could help practitioners improve the final quality of the product (because of its ability to highlight areas of potential failure), but cause a delay in the date of launch (because of the extra time needed to implement it). In a sense, each tool has its unique benefits and disadvantages in specific and limited areas of NPD performance.
- While some tools appear to individually create performance benefits in particular areas of NPD, certain combinations of tool usage, or certain complex patterns of tool usage, also appear to selectively enhance NPD performance, but in ways more limited than previously considered. For example, I found that five of the 12 tool categories (categories based on the 12 NPD perspectives) significantly correlates with certain performance areas, providing some support for the earlier findings of Maylor (2001). The importance of this finding is not

necessarily the identification of specific combinations of tools that may collectively yield performance improvement in a particular area or areas, but the awareness of the propensity of tools to contribute both individually and in combination with others, to improved performance. Still, it is very insightful to compare the relative contributions of the 12 tool categories in terms of the ratio of positive performance correlations to the number of tools in each category. Unexpectedly, six tool categories (including the categories of market research and product strategy) outperform engineering and design tools, which again serves as a reminder of the importance of other disciplines in NPD.

8.1.10 Tool Satisfaction

RQ8: How do practitioners experience tool application?

As one would expect, tool users are very satisfied with some tools, but not so satisfied with others. Generally, the more popular tools are also the ones that users find more useful. There are a number of exceptions or outliers, though, where a number of low-use tools such as 'selection criteria', 'computer integrated manufacturing', 'fault tree analysis', 'knowledge management', and 'morphological analysis' achieve relatively high usefulness ratings.

My research shows that only approximately 40% of the tools in this study achieve mean satisfaction levels greater than 60%. Similar research among larger firms came up with both contradictory and similar results. Tidd and Bodley (2002), for example, found corresponding levels of 84% for high-novelty projects and 72% for low-novelty projects (bearing in mind that the latter study involved only 32 tools, some of which are different from the current study). Research conducted in Taiwan (Yeh, et al., 2008a), however, generally shows lesser levels of satisfaction than those of Tidd and Bodley, and the current research. Only three out of 26 tools in the Taiwanese survey achieved ratings above 3.5 (62.5%). They are 'CAD/CAM/CAE' (4.14), 'specific design software' (3.63), and 'project management' (3.60). More than half the tools in their research achieved ratings below three, which indicates relatively low levels of satisfaction. The last three in these rankings were 'TRIZ' (2.06), 'Taguchi method' (2.29), and 'DfX' (2.37). It therefore seems that tool satisfaction levels vary from country to country and that it is not related to firm size. What all the findings have in common though, is that many tools rated as relatively more useful than others, are not commonly used. Examples of such tools from the current research are 'selection criteria', 'roadmapping', 'configuration management systems', 'gamma prototype', 'statistical process control', 'decision screens', ‘computer-aided manufacturing’, ‘voice of the customer’, ‘cross-functional teams’, ‘post-launch review’, and ‘lead user’.

On several occasions throughout this study I have demonstrated the often complex nature that exists between different variables. One such relationship is between tool popularity – measured as tool diffusion among firms – and the perceived usefulness of tools. The findings provide strong support for the notion that tool popularity determines users’ perceived usefulness (rejecting the null hypothesis $H1^{useful}$). Yet another such relationship is the one that exists between thoroughness of tool use, and users’ perceived usefulness of tools. I found empirical evidence at a statistically significant level to suggest that the more thorough use of tools could result in greater satisfaction, in terms of usefulness, with these tools (rejecting the null hypothesis $H2^{useful}$).

The findings of my interviews confirmed that tool satisfaction is a function of several factors, not only a tool’s perceived usefulness (a fact not explicitly stated by NPD theory). In turn, a tool’s perceived usefulness can be expressed in efficiency gains, effectiveness, and flexibility of use. Other obvious satisfaction factors include a tool’s adaptability and its perceived user friendliness. A more subtle factor that finds favour among practitioners is the ability of a tool to unify a team; to foster team relations. What my participants are referring to here are not tools such as teambuilding or cross-functional teams, but tools that were designed for completely different purposes, but somehow manage to enhance team spirit and improve the overall cohesiveness of teams. This concurs very well with Knott’s (2008) observation that users sometimes use tools merely as a source of inspiration without utilising them fully for the purpose for which they were necessarily designed. The business-planning tool as used by Company A had exactly this effect, it created a sense of shared interest and common goals that bonded the members of the team together and “put everyone on the same foot”, while the plan served no purpose other than that. Other tools in this category include ‘brainstorming’ and ‘design review meetings’.

My study also uncovered several factors that contribute towards general dissatisfaction with certain tools, which confirms what others have found before me. My survey participants rated the usefulness of 22 out of 76 tools (almost 30%) below 50%, tools such as ‘design of experiment’, ‘TRIZ’, ‘DfX’, ‘QFD’, and ‘conjoint analysis’. What struck me about this situation is not only the fact that these particular tools have low diffusion among firm rates, but that users in small firms generally do not receive formal training in any tools (a fact that clearly transpired from my case interviews). This explains why users find these tools not useful; it is very likely that they are not competent in using these tools. With this understanding, I am able to support Notargiacomo's (2009) views that a possible reason for tool dissatisfaction could be because the tool was used by a person who was not suitably trained in using it, and that the value of a tool is tied to the skill of the person using it. In view of this, one has to seriously question the ability of users to effectively rate a tool's usefulness (as they did - see Figure 24, p. 120) as users' tool competence is an unknown factor; an independent variable with huge variability.

Finally, Participant D3's aired frustrations with the focus group tool (see Section 6.4.6, p. 183) provides some support for Jarzabkowski's (2004) 'boundary conditions' idea that suggests that each tool has a 'sweet spot' of conditions in which it adds value, but struggles to do so outside that spot. Clearly, Company B hit that 'outside spot' when they conducted consumer focus groups for their new-to-the-world product (as visionary thinking realistically cannot be expected of consumers). As my study shows, users often find it useful to use tools outside the scope for which they were originally designed and often have success in doing so, but they should be aware that on occasion when a tool does not succeed in obtaining the desired results, it is not necessarily the tool that is at fault. Studies of this nature should be aware that users' negative tool experiences as described here may also be because of users' tendencies to use tools outside their 'sweet spots'. Rigby (1993, p. 15) provided useful advice in this regard when he said that users should become fully acquainted with the strengths and weaknesses of each tool prior to using it, then creatively combine the right ones in the right ways at the right times. "The secret is not in discovering one magic tool, but rather in learning which tools to use, how, and when."

8.2 Implications for Theory

In Chapter 2, I provide an overview of recent research in the field of NPD tools predominantly carried out among large high technology firms. This led me to identify gaps in the literature that I systematically addressed through empirical investigation in Chapters 5, 6 and 7. As such, this thesis presents a number of implications and contributions for theory that I summarise in this section.

Differentiating factors of my research include the facts that I carried out a very comprehensive study of tool use among small, high technology firms, thereby adding to the existing body of knowledge that until now was derived mostly from piecemeal studies among larger firms. Not only was I able to carry out comparative studies, but I uncovered many new insights into aspects of tool application, irrespective of the size of firms studied. The main differentiating factor, however, was the systematic and inclusive use of 12 perspectives on the NPD process, which resulted in the inclusion of a far larger scope of activities and tools than in any past research. This is significant because I studied tools that fall outside the scope of design, engineering and market research, which have been the primary focus of past research. Other activities and tools, such as product strategy, knowledge management, learning and review, arguably play a big part in successful NPD. My findings support this view, as I was able to identify, for the first time, the impact on NPD performance when firms use tools such as ‘PESTE analysis’, ‘Porters Five Forces’, ‘scenario planning’, ‘product life cycle’, ‘knowledge management’, ‘configuration management system’, ‘design review meetings’, ‘customer satisfaction tracking’, and ‘post-project review’. In other NPD activities, where it was possible to make direct comparisons with prior research, my findings show consistent levels of support for a number of tools (e.g. ‘concept testing’, ‘in-market testing’, ‘project management’, ‘value analysis/value engineering’, ‘brainstorming’) as exceptional contributors to enhanced NPD performance.

One of the conclusions of my study is that NPD tools is too broad a concept to study ‘under one heading’, as there are too many undercurrents of tool application. In this study, I introduce several different categories of tools that each contributes uniquely to achieve a better overall understanding of tool usage:

- A 12-perspective categorisation of tools (Section 2.2.6, p. 22): The 12 conceptual categories are: Engineering and design, Product strategy, Marketing and market research, Project Finance, General management, Manufacturing, Creativity and problem solving, Information management, Team support, Risk management, Learning and review, and Decision making. This categorisation scheme acknowledges and emphasises the multi-functional, multi-disciplinary nature of product development. Its understanding and use may help guard against the natural tendency of practitioners to approach product development predominantly from a state-of-the-product perspective.
- A categorisation scheme based on users’ tool needs (Section 7.4, p. 215): The tool needs hierarchy contributes to theory as I demonstrate here how it provides a deeper level of

understanding into contemporary stage models of NTBF growth, such as Kazanjian's (1988). Kazanjian was one of the first scholars who realised that the normal life-cycle models of business may not be appropriate to correctly describe the stages of growth in technology-based ventures. At the time, he argued that existing models did not take into account the role of industry, technology and other situational variables. His grounded theory and empirical research led him to formulate the so-called Stage-of-Growth model for NTBFs consisting of four stages. He based the formulation of the stages on the notion that the particular dominant problems that NTBFs face at a given time is strongly associated with the venture's position in a particular stage of growth. Several scholars (Almus & Nerlinger, 1999; Dodge & Robbins, 1992; Hanks, Watson, Jansen, & Chandler, 1993; Kazanjian & Drazin, 1990) have since validated and contributed to this model, and today it is widely acknowledged and cited by many scholars in the field. In essence, the tool needs hierarchy can also be seen to be based on the dominant NPD problems faced during any project. In Table 39, I link the four levels of the tool needs hierarchy and respective prevailing conditions with what appear to be corresponding and matching stages in Kazanjian's Stage-of-Growth model. The good fit obtained between tool needs and growth stages bodes well for the external validity of the tool needs hierarchy.

- A categorisation scheme based on tool popularity (Table 17, p. 112). In this instance the observed levels of differing tool diffusion among firms determine tool popularity. On this basis, I identified five categories ranging from infrequently-used tools (tools adopted by 20% or less of firms) to popular tools (tools adopted by more than 70% of firms). This schema serves as a useful benchmark for small firms that they can use for benchmarking purposes with other small and large firms.
- A categorisation scheme based on a tool's propensity to enhance NPD performance (Table 21, p. 132 and Table 22, p. 133; Section 5.2.17, p. 145). In my discussion thus far I have only labelled the top category of tools as 'high-performance' tools - those tools that yield positive correlations with four or more of the 12 NPD performance measures, but it is a simple exercise to use the information in these tables to identify medium- and low-performance tools. This categorisation scheme may serve as a useful guideline in selecting tools with the specific aim of enhancing performance in a particular area or areas.

I acknowledge that any attempt at categorising tools has its limitations, and it is no different for any of the categories I propose here. For example, because of their low diffusion among firms, some tools in this study have very small sample sizes that affect the statistical calculations, and may therefore appear in categories lower than where they truly belong.

Table 39. Linking NTBF growth with corresponding tool needs

Stage-of-Growth Model (Kazanjian, 1988)	**Tool Needs Hierarchy** (emanating from current research)
Stage 1: Conception and development Primary focus on the invention and development of a product or technology; Structure and formality are non-existent with almost all activity focused on technical issues; Activities are implicitly and informally organised; Problems include construction of a product prototype and selling the business idea to financial backers	**Level 1:** Tools with a state-of-the-product and market orientation, focus on being effective **Dominant problem:** We are ineffective. Which tools can help create successful products? **Prevailing NPD conditions**: Start-up period characterised as chaotic, full of crises, lots of pressure on teams to perform, not enough time, tactical rather than strategic, and unstructured; team members preoccupied with the product concept and how it evolves into saleable product
Stage 2: Commercialisation Completing product development; Organisation largely resembles an NPD team; Problems and competences are largely technical; Focus primarily on learning how to make the product work well and how to produce it beyond prototype; Communication is face to face	**Level 2:** Tools with a problem-solving orientation **Dominant problem**: We experience problems. Which tools can help solve our product problems? **Prevailing NPD conditions:** Emergency situations; unforeseen circumstances; solve unexpected problems; make difficult decisions; respond reactively to situations
Stage 3: Growth Major problems are to produce, sell and distribute product in volume and to avoid being shaken out of the market as ineffective or inefficient; Problems: difficulty in building an efficient and effective task system; Experience constant state of change; Growth of hierarchy and advent of functional specialisation and move toward adding professionally trained, experienced people; Establish more formalised structure and reporting mechanisms; Formalisation of structure with functional organisational design	**Level 3:** Tools with a process orientation, focus on achieving efficiencies **Dominant problem**: We are inefficient. Which tools can help us work smarter and faster? **Prevailing NPD conditions:** Larger scope of things; Automation; Teams become more disciplined, procedures are developed for groups of activities; Formalisation
Stage 4: Stability Major problems / challenges: to maintain growth momentum and market position; Stable, functional, characterised by bureaucratic principles, formal structure, standardised and formalised rules and procedures; Developing 2nd and 3rd generation products	**Level 4:** Tools with a 'big picture' orientation, focus on effective management of resources **Dominant problem**: We have a short-term focus; we mainly operate on a tactical level. Which tools can help optimise our resource utilisation? **Prevailing NPD conditions:** Proactive in many ways; Big picture focus; Effective management of resources is important; Several concurrent NPD projects

This thesis also makes modest contributions in the form of a number of conceptually and empirically derived models that add new knowledge and understanding in the following areas:

- A model of NPD activity (Figure 8, p. 68). My empirical findings not only underwrite this model, but also integrate and articulate the distinct roles played in NPD by practices, practitioners and praxis. Through the follow-up research, I hope to have provided a basis for identifying more precisely the causes of good or bad NPD performance with regard to tool use. For example, where existing findings associate a specific tool with performance, the framework suggests what my findings confirm, namely that a number of factors are likely to mediate this association:

    1) The particular practice through which a tool is internalised in the firm (see Section 7.1, p. 200) is the first factor to mediate this association. An example would be strong peer pressure exerted from an organisational culture that expects very thorough use of a particular tool, as opposed to the same tool only residing with an individual user on an informal basis. Clearly, the former situation is bound to affect performance more so than the latter.

    2) The defined scope and degree of formalisation of a particular tool within a particular setting (Section 2.2.3, p. 15) may affect performance, as the earlier cited example of the 'NPD process' tool clearly demonstrates.

    3) The adaptations (customisation, reinvention, re-interpretation and modification - see Section 7.5, p. 224) practitioners make with a tool when they use it will most certainly mediate this association, and what is more, it (the praxis) will differ from one user to another; from one project to the next.

    4) Lastly, the findings indicate that circumstance plays a huge role in determining how thoroughly tools are used, for practitioners with the best of intentions (to use a tool thoroughly) are often forced to take shortcuts with tools that may have detrimental effects on performance.

- A model depicting typical phases in the tool adoption process (Figure 35, p. 201). While patterns of tool adoption have received some consideration in past research, the actual process of adoption has been covered inadequately. This model, which I derived through a process of induction, does not represent ‘better practice’ in any way. On the contrary, it is simply a reconstruction of a generic process that firms appear to go through, often in an unconscious, non-deliberate manner. The model by itself provides useful insights, especially the part that explains tool internalisation, but of more value perhaps is discovering the highly informal and unstructured approach of my sample firms in going about this important activity. Firms of any type or size can use this generic process as a starting point for establishing customised processes of their own.

- A needs-based model of tool selection for start-up firms (Section 7.4, p. 215). The extant literature provides several reasons why practitioners use tools, which by itself provides little more than motivational value. Past research also treats tools as a single concept when studying its use from a motivational point of view, which is over-simplistic. In an attempt to determine causality, the needs-based model goes further in describing circumstantial factors that explain why practitioners revert to certain categories of tools during the different stages of a technology start-up’s life cycle. This is an example of a stimulus-response relationship (Cooper & Schindler, 2008). I elaborate further on this topic in Section 8.1.7 p. 247.

Where past research mostly aims at uncovering relationships between independent and dependent variables without making any attempt at determining causality, this thesis succeeds in addressing causality in a number of areas by combining case and survey findings. Examples include the identification of moderating factors that affect tool performance; a model explaining why practitioners use certain categories of tools at different stages in an NPD firm’s development; and sets of circumstances explaining why tools are sometimes used more thoroughly than at other times.

Finally, as far as I could determine, this study is the first to provide an operational definition for NPD tools and distinguishing it from other constructs such as practice, process and procedure. This adds much needed clarity to a field of study that is often plagued with confusing terminologies and jargons.

8.3 Implications for Practice

Based on my empirical findings and contributions to theory in the preceding sections, I present a number of implications and contributions for practice.

NPD process

From a managerial perspective, more formalisation and better structure with regard to the NPD process could be beneficial to small high technology firms as these factors are likely to 1) result in higher levels of tool application in projects, and 2) improve process performance in getting product out to market faster and launching it on time and within budget. Increased tool adoption may be desirable because, apart from helping practitioners get a job done, this research shows that most tools have the propensity to improve NPD performance in one or more ways. Table 21 (p. 132) and Table 22 (p. 133) provide useful guidance to practitioners in this regard. Regular review and redesign of existing NPD processes is advisable, as this will assist managers not only to identify opportunities for appropriate deployment of suitable tools, but also allow them to capitalise on the many benefits associated with robust idea-to-launch systems (Cooper, 2008).

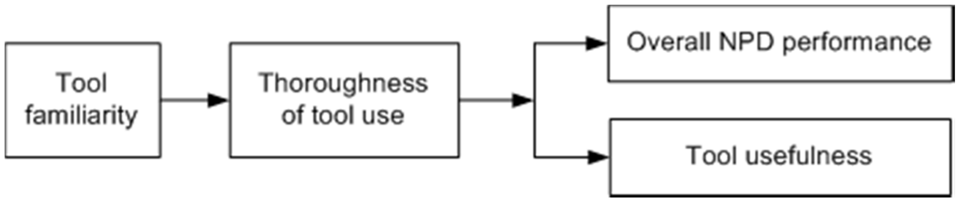
Innovation strategy

Few small NPD firms have innovation strategies in place to guide their NPD efforts. This is probably because of the small size of such firms, causing managers to discount the value of and need for strategising their NPD efforts, but as the results suggest, there are potential performance gains to be had from implementing an innovation strategy. While small teams can probably manage NPD activities sufficiently with few formal support systems and processes when executing relatively small projects, they should be ready to complement their NPD activities with the adoption of a broader scope of tools, other than the usual focus on engineering, design and marketing tools, when dealing with bigger projects, or when employing more people. Failure to adapt could potentially lead to product shortcomings and inefficiencies in current and future projects. Ideally, firms should take a holistic and balanced approach to NPD to lessen the probability of omitting important steps and activities, and apply tools accordingly.

Tool relationships

My research uncovered a number of interesting links between various aspects of tool use, underpinned by significant positive correlations that exist between these variables, depicted in Figure 39. Although these relationships may appear intuitive, the fact that they are empirically supported gives them some legitimacy.

Figure 39. Significant positive correlations between research variables



The apparent links in Figure 39 make a strong case for encouraging practitioners to get to know the tools they are using as well as they can. As a result, they are more likely to use their tools more thoroughly, and consequently find the tools more useful and achieve better overall results. Formal tool training is currently almost non-existent within small high technology firms, and as it is likely to improve tool familiarity levels, it could pay managers to invest in training programmes of this nature.

Reasons for using tools

My attempt at understanding how the tool needs of practitioners change over time, led me to develop a tool-needs model for new technology start-up firms in Section 7.4, p. 215. As needs or motivational factors drive behaviours that result in actions, the value of this model is in offering NPD teams a blueprint for understanding how tool selection in a project can be fast-tracked to achieve a state of optimum performance sooner rather than later. As my case evidence shows, NPD teams that are unaware of the natural progression upwards through the tool needs hierarchy learn so the hard way, often making costly mistakes and wasting time in the process, while more experienced teams in well-established firms operate more effectively and efficiently within all four levels at the outset when initiating new projects.

Flexibility of use

Also of interest, from a managerial perspective, are the interviews with practitioners in which they explain why they use low-flexibility tools more thoroughly than high-flexibility tools. This information can help managers create innovation supportive organisations (refer to the discussion on Innovation Management in Figure 6, p. 35) that encourage practitioners to use certain tools, perhaps ones identified as ‘mission critical’, substantially. For example, managers may decide among a selection of tools, for which they generally desire high levels of thoroughness of use, which ones to ‘enforce’ via strong supervision, formal procedure, peer pressure or organisational culture.

Measuring the success of different project strategies

In Table 20 (p. 129) I present a fine-grained analysis of performance relationships across different project strategies. Based on this data, I propose guidelines that could help practitioners set priorities for what to focus on in specific circumstances. Before discussing individual project strategies, I note that across the board the process-related performance measures, together with the profit measure (the top six performance measures in Table 20), achieve lower ratings than the product-related ones. Of particular concern is not meeting profit goals, as it indicates that small high technology firms are not reaping the financial rewards they aspire to with their NPD efforts. A possible remedy for this problem is to follow my earlier recommendations in the 'NPD process' section (Section 8.1.1 p. 237).

With an overall Performance Index of 3.08, the cost-reduction strategy appears to be the least successful among the six. As the name suggests, the main objective of this strategy is to reduce costs where possible while presumably maintaining product quality and performance. Consequently, the best indicators of success would be in meeting profit goals and satisfying customers, each of which respondents rated very low (2.50 and 2.00 respectively). Meeting quality (3.00) and performance (3.00) specifications are also important considerations in cost-reductions, but are currently far below their respective performance means (4.10 and 4.13), which is a possible explanation for the relatively low customer satisfaction. Managers therefore need to re-assess their current cost-reduction tactics to avoid seeking increased performance in one area (and, in my study, not achieving it) at the expense of performance in other areas.

Apart from meeting profit goals (in this study, not very successfully), achieving competitive advantage and being accepted by customers are the main objectives of product repositioning projects. With a value of 3.67 (lower than the 4.15 performance mean across strategies) it appears that in two important measures this strategy performs poorly relative to the others. Furthermore, at 3.40 it has the second lowest overall performance index among all the strategies. Repositioning projects are typically low-investment, market-driven strategies for which profit expectations are relatively low. Another aim of these strategies is to give ailing products, often near the end of their life cycles, new life - hence it is not surprising that this strategy often does not lead to competitive advantage. 'Customer acceptance', on the other hand, achieves the relatively high score of 4.29, which is by quite a margin higher than the 3.97 performance mean across strategies. This is encouraging as it shows that NPD efforts will succeed in extending the life cycles of these products.

When implementing incremental improvement strategies to currently sold products, firms hope to increase customer satisfaction and reclaim competitive advantage through improved product performance. My assessment provides little evidence that firms are achieving this — I observe relatively low performance in all areas and slightly below mean performance in the most relevant success measures. Incremental improvements are usually small projects, and firms may be inclined not to commit their best resources towards these projects. These findings furthermore strengthen the particular notion of small firms portraying their preference for pursuing more interesting new things at the expense of developing an existing product to its full potential. The saying “if it is worth doing, it is worth doing right” may specially ring true for this strategy.

Project strategies aimed at adding to existing product lines are the most profitable of the six under consideration. This strategy does particularly well in tapping into new sub-segments of the market, achieving scores of 4.38 in ‘customer acceptance’, and 4.31 in ‘customer satisfaction’. It does reasonably well in defending the product line from competitive attack (achieving a 4.15 score for ‘providing competitive advantage’), but ends up surprisingly below the performance mean with regard to ‘meeting product performance specifications’. This could be indicative of firms giving insufficient attention to those projects, perhaps because the product platform already exists and hence they have to prove that the product works.

New-to-the-firm project strategies deliver somewhat surprisingly good results in areas where one would logically expect lesser performance, notably in ‘adherence to budget’ (4.00) and ‘serviceability’ (4.50). As one would expect, ‘speed to market’ is an area of underperformance, both in absolute value (3.00) and relative to the other project strategies. Encouraging though, is the high score of 4.50 in ‘providing competitive advantage’, an indication that firms perceive they have succeeded in the marketplace. High scores in both ‘customer acceptance’ (4.33) and ‘customer satisfaction’ (4.33) are also promising.

Finally, while new-to-the-world ‘project strategies’ comes out top overall of the six in this study, it scores lower than one would hope for in its most importance performance measure - ‘customer acceptance’ (4.08). Although this is still above the overall mean for this measure, new-to-the-world projects score higher in the two other most useful success measures, ‘customer satisfaction’ (4.31) and ‘providing competitive advantage’ (4.46). The lower score for 'customer acceptance' may be indicative of firms having difficulty with initial market uptake.

These findings reveal a novel, more fine-grained pattern of relative performance by looking separately at six project strategies and 12 performance measures. Although not all of the data currently support definitive correlations, the contingency-based approach to measuring the strategy-performance relationship represents an opportunity to generate research findings with a direct and pertinent impact on NPD process and conduct.

Tools as performance enhancers

Apart from helping managers get a job done, the choice of tools used in a NPD project should be guided by the particular performance gains sought. The results point out, for example, that profit goals is a performance area that consistently under performs for all six of the major project strategies. Hence, firms wishing to improve performance in this area could revert to using any or all of the 10 tools that were shown to have positive correlations with profit performance: 'brainstorming', 'design review meetings', 'customer satisfaction tracking', collaborative product development', 'needs analysis', 'concept testing', 'in-market testing', 'concept statement', 'project management' and 'business case'. In broader terms, it was shown that four tool categories, in particular, have very high performance ratios relative to the other eight categories: Market Research, Product Strategy, General Management and Learning & Review. From a purely performance perspective, firms are well advised to adopt and apply tools in these categories thoroughly.

However, practitioners should also be aware of the potential disadvantages of each tool so they can make the trade-off between potential 'gains' and 'losses' in deciding to deploy a tool in a particular situation. Two questions need to be asked before selecting and implementing a tool: 1) would a tool's potential benefits outweigh its associated adverse effects? and 2) would the time and money invested in implementing the tool generate financial and other returns that exceed the value of the invested time and money? Once chosen, such tools should be implemented in the most thorough manner - for as I have shown, more thorough tool implementation is associated with improved NPD performance, often significantly so.

A large number of tools appear to individually create performance benefits in particular areas of NPD. The results, summarised in Table 21 (p. 132) and Table 22 (p. 133), provide excellent guidance for firms wishing to improve their NPD performance with respect to any of the 12 established indicators. For example, if a project team wished to improve its performance with respect to product quality (PM8 performance indicator), it should emphasise using ‘alpha prototype’, ‘VA/VE’, ‘limited roll-out’, ‘control charts’, ‘knowledge management’, ‘benchmarking’, and ‘customer satisfaction tracking’ (tools showing significant positive correlation in the PM8 column).

In practice, every project is unique - having different requirements - hence it is with caution that one would recommend a specific selection of tools for inclusion in NPD projects. Having said this, it is worth noting that in view of the overall findings, a number of tools stand out in terms of their superior association with performance enhancement, usefulness, and thoroughness of use (usability). As such the following tools come highly recommended: ‘in-market testing’, ‘concept testing’, ‘needs analysis’, ‘project management’, ‘customer satisfaction tracking’, ‘brainstorming’, and ‘design review meetings’.

Conceptual NPD process framework

The multi-perspective NPD process framework developed in Chapter 2 (Figure 5, p. 26) and associated NPD activities (see Appendix 1) could provide a useful basis for practitioners to redesign or develop customised NPD processes for specific situations and purposes. Seen in its entirety, it provides a better starting point than existing models because it encourages practitioners to take a truly holistic approach to NPD by taking into consideration activities within all the perspectives that matter. This is important given that processes are often plagued by missing steps and activities (Cooper, 2008). It also allows for practitioners to select and modify activities and tools within the perspectives and stages, bearing in mind (for example) that radically new NPD projects would require less structure and more exploration than incremental projects (Kahn, et al., 2006). The concept of selecting and modifying activities from a comprehensive framework also allows for individual design of processes to meet different needs such as market-pull, technology-push, platform products, complex systems, etc. (Ulrich & Eppinger, 2008). By exercising a choice, process owners can customise their processes in a way to meet their exact requirements for particular industries, markets, or project strategies.

8.4 IMPLICATIONS FOR FUTURE RESEARCH

While this study made some new inroads into understanding the selection and use of tools in NPD, there is a great need for ongoing academic discussion on this topic. Based on the limitations of this study, this section proposes some potential areas for future research.

A major discriminator in this research is the significantly smaller size of firms that I studied compared to similar research done elsewhere. Following from this, it is reasonable to assume that the size of the NPD teams studied here (more than 90% of teams have less than ten members) is much smaller than that of corresponding research among larger firms for which team size is generally not specified. Realistically, one can expect the team characteristics of small teams to be markedly different from larger teams. Team characteristics include factors such as self-management, participation, task variety, potency, task significance, task interdependence, goal interdependence, interdependent feedback/rewards, social support, workload sharing, communication/cooperation within the team, training, managerial support, and communication/cooperation between teams. This study only focuses on uncovering patterns in tool adoption among small high technology firms without taking into account team, or project leader, characteristics. Future research on tool adoption that uses team characteristics as independent variables and distinguishes between small and large NPD teams will make a significant contribution to this field of study.

The prevalence of the small NPD teams studied here manifests in several ways in this study, although the cause-effect relationships are yet to be established. Among small teams, the expressed importance for factors such as team support, risk management, information management, general management, and learning and review is low - and generally accompanied by lower tool adoption rates in these areas than in the more functional or technical areas such as engineering and marketing. This is to be expected, as by the nature of its organisational and geographic structures, members of small firms work in close proximity to each other, communication among members is frequent and informal, individuals are not assigned to functional departments, and on-the-job learning is assumed and expected, but not necessarily organised. As such, there is probably less need among small high technology firms than among large firms for the mentioned ‘people-type’ processes in NPD as to some degree they already exist, albeit in informal, non-structured ways. This is also a potential area where future research can compare the observations of this research with that of larger firms in order to determine differences in 'effective practice' between small and large firms.

With regard to the NPD process, I found that the level of process sophistication significantly correlates with process performance measures, which include 'speed to market', 'launched on time', 'adherence to budget', and the 'degree of inter-functional cooperation'. This means in the first instance that it pays to have a process, and secondly, that gated-processes executed by cross-functional teams give better results than less structured processes executed by functional teams. The fact that there is no significant association between the level of process sophistication and the seven mostly product performance measures — 'providing competitive advantage', 'meeting product performance and quality specifications', 'achieving customer acceptance', 'satisfying customers', 'serviceability' and 'profitability' — may be indicative of low NPD process proficiency levels among small firms. To test this proposition, I suggest future research should firstly determine the types of activities that small firms engage in and the stages they incorporate in their NPD processes, and secondly, investigate how well firms perform these activities, stages, and the NPD process as a whole.

The survey findings furthermore indicate that firms guided by some form of an innovation strategy appear to obtain better NPD outcomes than firms that are not. While I defined the term 'innovation strategy' as 'the firm's written positioning statement for developing new technologies and products' in the survey, I did not explain its various constituent parts and therefore recommend verification of the findings in follow-up research with a greater level of enquiry into this phenomenon. For example, when innovation strategy is studied in terms of product portfolio decisions, its fit with overall company strategy, the allocation of resources, goal setting, and the identification of required innovative capabilities for planned projects, may reveal far greater insights and relationships than what was possible with the current study. Such work may also provide better insight into possible reasons why only two performance measures out of 12 tested significantly, although the remaining ten consistently provided marginally better results when an innovation strategy was present than when it was not.

As far as I could determine, this study is the first to measure NPD success and failure at the project level in the small-firm setting. It is also a first attempt at building on the basic ideas of Griffin and Page (1996) that different project strategies have different objectives that require different performance measures. In doing so, I found my data exhibits interesting patterns, raising important questions that were not raised before, and which need answering elsewhere.

Finally, it would be interesting and useful to conduct in-depth qualitative research to obtain an explanation and understanding of why the three project strategies of cost reductions, product repositionings and incremental improvements (categorised together as incremental innovations) generally achieve inferior results to the more innovative and radical-type projects.

Carried out in New Zealand, this thesis describes a holistic study of 76 tools in small high technology firms. A logical extension of this research would be to confirm the findings for small firms elsewhere, using the research framework and models developed in this study. It would also be insightful to make cross-national comparisons with companies of different size and culture in other parts of the world.

8.5 CONCLUSION

This thesis sheds some new light on how practitioners in small high technology firms can better select and use tools to bring new products to market faster and more successfully. It is undeniable that tools are an integral part of NPD activity and that it plays a crucial role in determining the ultimate NPD success of firms, but in successful NPD it is the types of activities that matter first and foremost, not the list of tools a firm seeks to adopt. It is only when the right tools are selected and thoroughly implemented and integrated into a firm's process and activities that real benefits eventuate.

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Appendix 1. Example Sets of NPD Activities

The following exhibits *contain* example sets of activities within the 4-stage, 12-perspective NPD process (see *Figure 5*, p. 26). It is not intended to be a comprehensive set.

Exhibit 1: Product (R&D, Design & Engineering) Activities

Stage 1

- Identify opportunities in the market for business or technology gaps (market pull) (Whitney, 2007).
- Generate ideas by stimulating and developing new ideas that can lead to new products and technologies (technology push) (Koen, et al., 2002).
- Carry out a preliminary technical assessment and selection of the main and associated technologies to identify the technical possibilities and risks (see Exhibit 9).
- Develop and enrich the idea by taking it through any number of non-linear development iterations as required, and finally consolidate it into a clear concept definition (Koen, et al., 2002).
- Consider product platform and architecture (Ulrich & Eppinger, 2008).

Stage 2

- Carry out further concept development in pursuit of additional value-adding product options (functionality), optimizing outcomes (performance measures) or setting objectives for overcoming constraints (Ulwick, 2005).
- Complete an initial (primary) industrial design of the product (Ulrich & Eppinger, 2008).
- Carry out a technical feasibility study by building and testing experimental prototypes (Ulrich & Eppinger, 2008).
- Define the product using a "sharp and fact-based" definition (Cooper, et al., 2004c). This involves defining the product's features, requirements and specifications, and may include a list of optional features.
- Strive to maintain as stable as possible product specifications throughout the development stage as this practice will prevent situations leading to longer time to market (scope creep) (Cooper, et al., 2004c).
- Involve suppliers in product development (Handfield, Ragatz, Petersen, & Monczka, 1999).

Stage 3

- Generate alternative product architectures and define major sub-systems and interfaces (Ulrich & Eppinger, 2008).
- Conduct further and more detailed industrial design of the product (Ulrich & Eppinger, 2008). Design features such as maintainability should be incorporated into product design. Other important design considerations include the selection of appropriate materials based on a consideration of functionality and cost, and the selection of appropriate manufacturing processes based on a consideration of functionality, sustainability, materials and cost (see Exhibit 6).
- Build working prototypes (secondary development). It is often necessary to develop a series of prototypes, each at a more advanced stage of development than the previous one, until the product specifications are met (Onuh & Yusuf, 1999).
- Complete detailed design which includes definition of part geometry, selection of materials, assignment of tolerances, and completion of industrial design control documentation (Ulrich & Eppinger, 2008).
- Conduct further (tertiary) development and design that result in a pre-production (gamma) prototype of which the design specifications have been 99% finalized (Tidd & Bodley, 2002).

Stage 4

- Build the final production (pilot) prototype and finalize and freeze the design specifications (Handfield, et al., 1999).
- Conduct thorough product tests to determine reliability, life and performance (Ulrich & Eppinger, 2008).
- Obtain regulatory approvals (Ulrich & Eppinger, 2008).

Exhibit 2 Product Strategy Activities

Stage 1

- Determine the concept's strategic fit with corporate goals and test its alignment with the firm's competencies and intended competence development (Salomo, et al., 2007).
- Articulate the company's strategic intent with the proposed project (Schilling & Hill, 1998) and align the project with stakeholder values.
- Ensure that R&D and NPD have matching agendas and plans and that project priorities are consistent with product strategy, portfolio plans, and resource availability (Khurana & Rosenthal, 1997). Seek balance among multiple NPD projects belonging to different platforms/product lines (e.g. risks, novelty).
- Quantify and qualify the concept's tangible and intangible benefits to the company, potential licensees and buyers (Allen, 2003, p. 40).
- Identify the main potential drivers of market success for this new product concept (Browning, Eppinger, Whitney, & Deyst, 2002).
- Understand the new product's related IP landscape and formulate an appropriate IP strategy (Samson, 2005). This includes the NPD effort's IP needs, existing IP and prior art, competitive IP, new IP that might be generated, and any IP-related risks (Rastogi, Shinozaki, & Kaness, 2007).
- Formulate a strategy for co-development and in-licensing (Belliveau, Griffin, & Somermeyer, 2007, p. 341). Use strategic alliances to gain rapid access to enabling technologies (Schilling & Hill, 1998).

Stage 2

- Assess all available options for commercialising new IP and select the most appropriate pathway. Options include conducting product development and manufacturing in-house, having parts of it sub-contracted, outright selling of IP, establishing joint ventures for joint-development, licensing, in-licensing, being acquired by another company, or spinning-off new companies (Allen, 2003).
- Choose and monitor alliance partners very carefully (Schilling & Hill, 1998).
- Negotiate and execute agreements with third parties that might be involved in the NPD project (Rastogi, et al., 2007). Take the necessary precautions to protect IP before revealing

any commercially sensitive information to third parties.

- Decide on a specific market entry strategy (first to market, fast follower, niche, reactive) (Adams, 2004).

Stage 3

- Formulate product strategies. A number of strategies need to be crafted, some of which may already be conceived during the previous stage.
  - ➢ Positioning Strategy – specifying how the product will be positioned in the eyes of the customers relative to competitive products with regard to features, quality, price and branding (Park, Jaworski, & Macinnis, 1986).
  - ➢ Financing strategy – setting out how the organisation plans to finance the product's life cycle stages to meet the set objectives. Cited as a common cause of new product failure, it is vital to provide sufficient resources to finance product development, product launch, and the growth phase - the latter which is estimated to require up to two-thirds of the total investment (Udell & Hignite, 2007).
  - ➢ Product lifecycle strategy – anticipating the expected characteristics of the product life cycles after launch to forecast product performance and provide a framework for marketing strategy (Bevilacqua, Ciarapica, & Giacchetta, 2007).
  - ➢ Market entry strategy – deciding on which market segments to target and avoid, anticipating and countering competitive risks, and deciding on the most effective communication and sales channels (Cravens, Piercy, & Prentice, 2000).
  - ➢ Launch strategy - As effective product launch is a key driver in a new product's overall performance and often the single costliest step in NPD (Di Benedetto, 1999), it is important to prepare for it well both in terms of types of activities to include and the timing of the launch. The launch strategy should include objectives for all elements of the marketing mix, as well as statements of launch control, timing and speed, and the anticipated response of competitors (Ottum, 1996). Timing of the launch must be optimized from the point of view of the company, the competition, and the customer.

Stage 4

- Do IP clearance prior to product launch by ensuring that any new IP included in the new product is suitably protected (Rastogi, et al., 2007).

Exhibit 3 Market Activities

Stage 1

- Carry out market research with customers and stakeholders that will form the basis for the concept/product definitions (Kahn, et al., 2006).
- Do a quick and preliminary assessment of the concept's market potential, need level, and customer requirements at an early stage, well before the initiation of a project. This is likely to result in the early identification of potential target segments (Brown & Eisenhardt, 1995) that will guide the direction of product development.
- Identify lead users - this group represents future needs as they are ahead of the majority market, thus being one of the most important sources of market knowledge for product improvements (von Hippel, 1982).
- Identify competitive products (Cooper, et al., 2004c).

Stage 2

- Find out prospective customers' purchase intent before Stage 3 begins (Brady, 1986). The alpha prototype can already be used for obtaining end-user reaction and feedback if sufficient IP protection is in place.
- Collect information on customer price sensitivity for the new product (Cooper, et al., 2004c).
- Clearly define the product's benefits to be delivered to customers – also known as the value proposition (Cooper, et al., 2004c).
- Describe and estimate the size of the target market(s). This activity involves determining and describing the characteristics (demographics) of the market segments at which the product will be targeted.

Stage 3

- Carry out In-Market testing via focus groups with customers, or having customer tests of products done under real-life conditions. Each iteration of the product (beta prototype) should be tested with the customer as it is being developed (Cooper, et al., 2004c).
- Identify product sustainability factors to guide design considerations (Petrick & Echols, 2004).

Stage 4

- Carry out test marketing (Ulrich & Eppinger, 2008).
- Develop promotional and launch materials (Ulrich & Eppinger, 2008).
- Place early production with key customers (Ulrich & Eppinger, 2008).
- Determine the new product's performance profiles.

Exhibit 4 Project Finance Activities

Stage 1

- Provide planning goals (Ulrich & Eppinger, 2008).

Stage 2

- Carry out a Financial Feasibility study (Anonymous, 1986).

Stage 3

- Facilitate make-buy analysis (Ulrich & Eppinger, 2008).

Exhibit 5 General Management & Planning Activities

Stage 1

- Provide a brief summary of the concept's business case (scope and magnitude of the opportunity) for inclusion in the concept statement (Dunham, 2002).
- Establish specific goals for the project team to attain prior to initiating the project. Goal flexibility may be required at times, however, goal stability throughout the devlopment process has been shown to significantly enhance NPD performance (Salomo, et al., 2007).
- Map and include a preliminary action plan for the proposed project in the concept

document. The more intensively new projects are planned prior to the start of development, the more both market and technical uncertainties are reduced (Nagahira, et al., 2006).

- Develop a Project Plan and allocate project resources. Project planning addresses issues concerned with the actual management of the product development process (Salomo, et al., 2007) and involves a detailed analysis of the work breakdown structure and the use of milestone and resource plans (Meredith & Mantel, 1995).
- Review and confirm the NPD process. The Project Manager does this in consultation with the Process Manager and other team members if required (Skalak, Kemser, & Ter-Minassian, 1997).

Stage 2

- Analyze the Industry. This activity includes collecting competitive information regarding products, pricing and strategies, and gaining an understanding of how the industry works and what opportunities and threats it presents. Such knowledge makes it easier to find appropriate strategic partners, customers, money sources, and effective distribution channels (Allen, 2003).
- Manage the NPD project. Project Management (PM) is concerned with the processes that turn the inputs into marketable products.

Stage 3

- Develop the Business Plan. It ties together all aspects of the NPD project and the product's life-cycle (Shepherd & Ahmed, 2000).
- Identify service issues (Ulrich & Eppinger, 2008).

Stage 4

- Train the work force (Ulrich & Eppinger, 2008).

Exhibit 6 Manufacturing Activities

The activities listed in this exhibit were mainly derived from (Mital & Desai, 2007) and (Ulrich & Eppinger, 2008).

Stage 1

- Understand supply chain (resource) and production capabilities, constraints, and risks.

Stage 2

- Identify and satisfactorily address any manufacturability and regulatory compliance issues and deliver a set of documentation that describes the proposed production processes.
- Estimate manufacturing cost.
- Determine supplier involvement for raw materials and key components and select the most suitable ones based on formal supplier certification programmes.
- Assess production feasibility.

Stage 3

- Design the production tooling. The development of the near-final prototypes goes hand in hand with the design and setting up of the production tooling. Begin procurement of long-lead tooling.
- Define and design piece-part production processes and plant.
- Define quality assurance processes.
- Develop the Production Plan (capacity, inventory, logistics, etc.).

Stage 4

- Facilitate supplier ramp-up.
- Refine fabrication and assembly processes.
- Carry out a series of trial production runs and evaluate the early production output.
- Refine fabrication, assembly and quality assurance processes.

Exhibit 7 Creativity and Problem Solving Activities

Stages 1-4

Stimulate new ideas and develop solutions to NPD problems of a conceptual, technical, or market nature (Whitney, 2007).

Exhibit 8 Information Management Activities

Stage 1

- Ensure that systems and procedures such as documentation of project information, storage and retrieval systems for project information, and information reviewing practices are in place to capture all new information and knowledge (implicit and explicit) that will be generated over the product life cycle (Lynn, Reilly, & Akgun, 2000).

Stage 2

- Track the types and number of product changes (engineering change requests) in each project phase (Nadia, Gregory, & Vince, 2006).

Stage 4
Put mechanisms in place for obtaining customer feedback (Di Benedetto, 1999).

Exhibit 9 Risk Management Activities

Stage 1

- Carry out a preliminary risk assessment. The main associated risks of NPD projects are technical and market (Allen, 2003).
- Attempt to minimize uncertainties and risks as the more both market uncertainty and technical uncertainties are reduced during the front end, the higher is the effectiveness of NPD projects (Nagahira, et al., 2006).

Stage 2

Conduct a thorough risk assessment and planning for the proposed project. The complete activity involves the forecasting of various sources of risk and preparing for and reducing their consequences (Chapman, 2001; Githens, 2002; Jaafari, 2001).

Stage 3

Carry out advanced Risk Planning: Only after approval has been granted at Stage Gate 2 will the second main risk planning activity be carried out. This involves a risk- or contingency-planning activity that establishes a plan to constantly monitor the actual progress of project implementation (Salomo, et al., 2007).

Exhibit 10 Team Support Activities

Stage 2

- Appoint the project team. Each project should have a core team, led by the Project Manager, that remains on the project from beginning to end (Kahn, et al., 2006) and should include members from R&D, marketing and operations (Song, Montoya-Weiss, et al., 1997) to ensure supportive functional involvement when required.
- Start the negotiation process with third parties to determine interest in the project and to establish terms of collaboration and/or terms for acquiring required IP.

Stages 3 and 4

Conduct scheduled design review meetings.

Exhibit 11 Learning and Review Activities

Stage 4

Some of the activities listed here may very well blend into the post-launch stage, but are increasingly seen to be part of the NPD process as they serve as excellent sources of ideas for making improvements to the NPD process and existing products, thereby increasing repeatability and consistency in the NPD process from one NPD effort to the next (Clark & Fujimoto, 1991).

- Ensure IP clearance prior to launch. The purpose of this activity is to ensure that any new IP included in the new product is suitably protected (Belliveau, et al., 2007, p. 281).
- Perform a Post-Launch Review (PLR) (Cooper, et al., 2004c). Useful sub-activities are:
  - Track customer satisfaction. This is an activity that starts on a relatively small scale prior to the launch among the customers who participate in the test marketing exercise, but really continues on a bigger scale after the launch and throughout the product's life cycle.
  - Monitor product reinvention suggestions/changes.

- Observe product usage with redesign in mind.
- Track product maintenance with redesign in mind.
- Evaluate NPD performance. Maintain a standard set of criteria for multiple review and evaluation of individual NPD projects (Kahn, et al., 2006). Employ evaluation software tools for tracking, storing and analyzing metric data.
- Evaluate NPD Process performance - appropriate performance metrics assess whether the NPD process is working well.

Exhibit 12 Decision Activities

Stages 1 to 4

- Evaluate the concept/product against four types of decision considerations that vary from stage to stage - market/customer, technology/capability, business, and project management (Deck, 2002). The specific decision criteria of each consideration need to be tailored to a company's context.
- Approve, postpone, or terminate the concept/project based on a review of the decision criteria.
- If approved, allocate sufficient resources for enabling the next stage's activities.

Appendix 2. Online Survey Invitations

Note: this letter was mailed to CEOs / Project Managers in 566 firms

[date]

The [title]
[salutation] [firstname] [lastname]
[company name]
[address1]
[address2] [postcode]

Dear [firstname]

Survey on New Product Development (NPD) Tools

I am a PhD student at the University of Canterbury, conducting an online survey on how firms use New Product Development (NPD) tools when developing new products. This study is part of an effort to learn how Kiwi firms can make better use of NPD tools in developing world-class products. My supervisors are Doctor Paul Knott and Professor Bob Hamilton.

It is my understanding that your organisation is involved in NPD. I am therefore inviting you to complete my Web questionnaire which looks at the tools you are using in your NPD efforts, what your experience has been with these tools, and whether these tools have met your expectations. To get the best possible information, I would appreciate it if you could you ask the person most knowledgeable with a particular NPD project to complete this survey, e.g. an NPD Project Manager, Process Manager, or Team Leader.

This survey will take about 20 minutes to complete and your identity and responses will be completely confidential. The results of the survey will be anonymous and you will not be identified in any publication or dissemination of the research findings.

I have enclosed a small token of appreciation as a way of saying thank-you for your help. You can also elect to receive an electronic copy of the research findings and go into the draw for **winning one of twenty $50 petrol vouchers**. Your chance at winning is approximately 1 in 5.

If you have any questions or comments about this study, I would be happy to talk with you.

Your involvement would be greatly appreciated.

Sincerely,

Gerrit Anton de Waal
Tel: 03 9407505
Survey address: www.toolsurvey.com Your Token (password): [token]

First email reminder:

Dear [firstname],

I recently sent you an invitation by mail to participate in an important research study I am conducting as part of my PhD studies at the University of Canterbury. This is just a reminder, kindly requesting you to help me with this.

As stated in the letter, this is an online survey on how firms use New Product Development (NPD) tools when developing new products. This study is part of an effort to learn how Kiwi firms can make better use of NPD tools in developing world-class products. My supervisors are Doctor Paul Knott and Professor Bob Hamilton.

To get the best possible information, I would appreciate it if you could you ask the person most knowledgeable with a particular NPD project to complete this survey, e.g. an NPD Project Manager, Process Manager, or Team Leader.

This survey will take about 20 minutes to complete and your identity and responses will be completely confidential. The results of the survey will be anonymous and you will not be identified in any publication or dissemination of the research findings.

You can also elect to receive an electronic copy of the research findings and go into the draw for winning one of twenty $50 petrol vouchers. Your chance at winning is approximately 1 in 5.

If you have any questions or comments about this study, I would be happy to talk with you.

Thank you very much for helping with this important study.

Sincerely,

Gerrit Anton de Waal
Email: [adminemail]
Telephone: (03) 940 7505
Survey link: www.toolsurvey.com

Second and final email reminder:

Dear [firstname],

I recently sent you two mailings about an important research study I am conducting as part of my PhD studies at the University of Canterbury. Its purpose is to learn how Kiwi firms can make better use of NPD tools in developing world-class products.

The study is drawing to a close and I am sending this final contact because of my concern that firms that have not responded may have unique NPD experiences from those who have. Hearing from everyone in my New Zealand sample helps assure that the survey results are as accurate as possible.

I also want to assure that your response to this study is voluntary and if you prefer not to respond, that's fine. The survey will take approximately 20 minutes to complete. Your answers are completely confidential and will be released only as summaries in which no individual firm's answers can be identified.

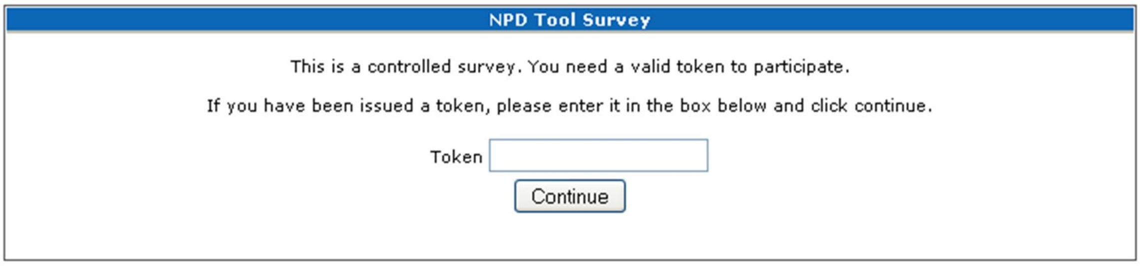
Remember you can also elect to receive an electronic copy of the research findings and go into the draw for winning one of twenty $50 petrol vouchers. Your chance at winning is approximately 1 in 5.

If you have any questions or comments about this study, I would be happy to talk with you.

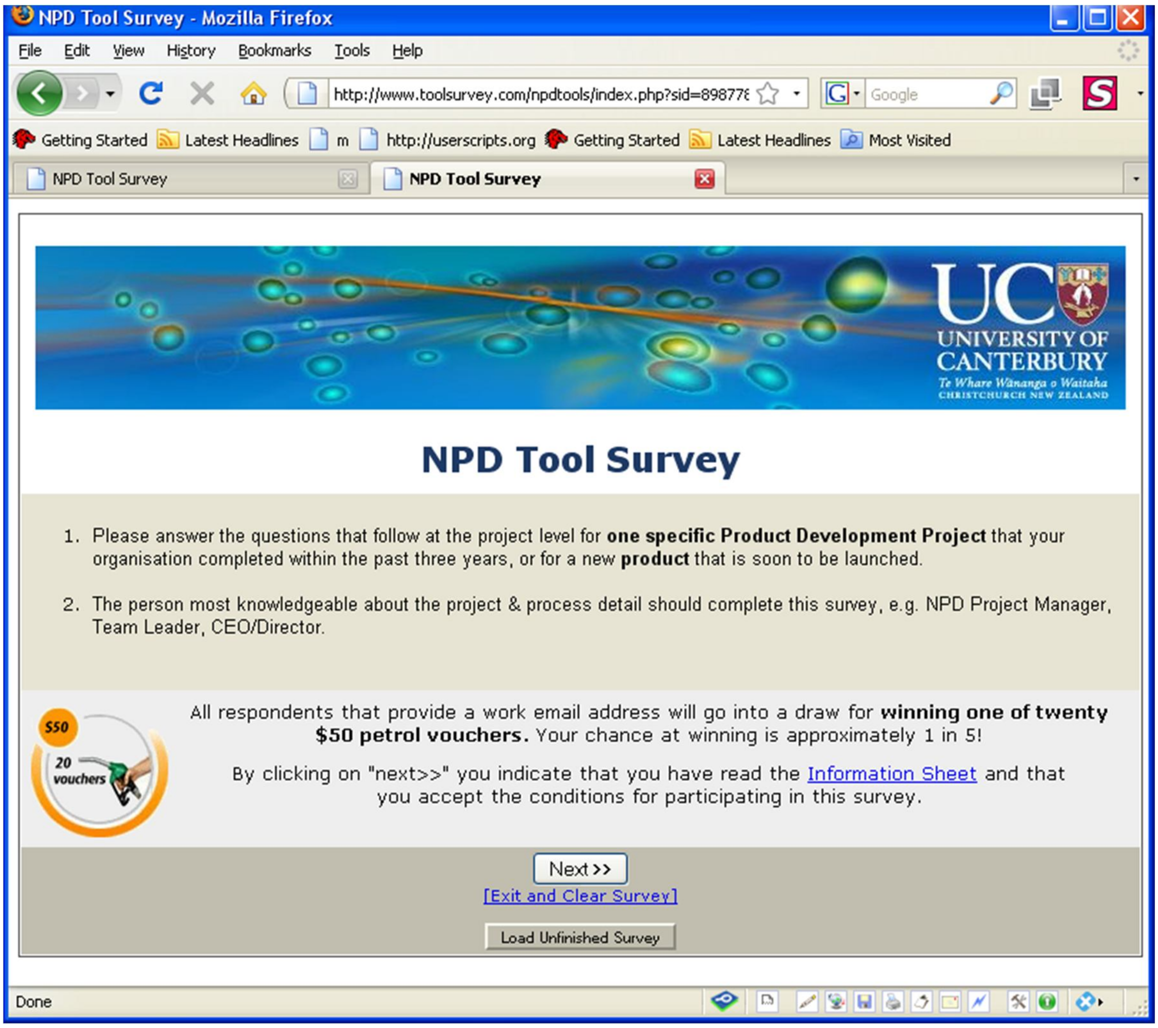
Thank you very much for helping with this important study.

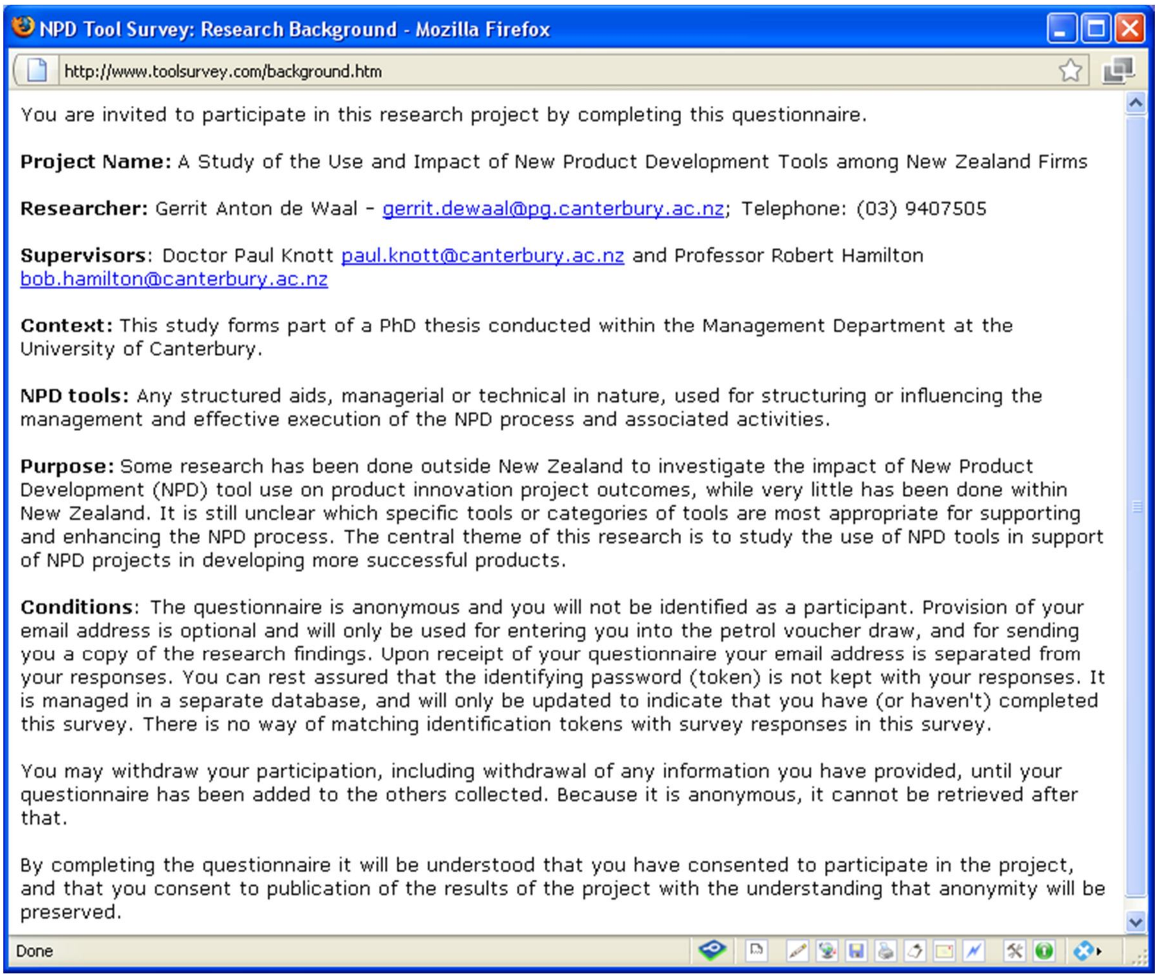
Sincerely,
Gerrit Anton de Waal
Email: [adminemail]
Telephone: (03) 940 7505
Survey link: www.toolsurvey.com

Survey participants were directed to the URL http://www.toolsurvey.com where they were prompted for a unique token in order to continue:



Once participants entered their unique tokens, they were presented with the Web page below. The 'Information Sheet' hyperlink near the bottom of the page opens the pop-up window with background information (shown on the next page).




NPD Tool Survey: Research Background - Mozilla Firefox

http://www.toolsurvey.com/background.htm

You are invited to participate in this research project by completing this questionnaire.

Project Name: A Study of the Use and Impact of New Product Development Tools among New Zealand Firms

Researcher: Gerrit Anton de Waal - gerrit.dewaal@pg.canterbury.ac.nz; Telephone: (03) 9407505

Supervisors: Doctor Paul Knott paul.knott@canterbury.ac.nz and Professor Robert Hamilton bob.hamilton@canterbury.ac.nz

Context: This study forms part of a PhD thesis conducted within the Management Department at the University of Canterbury.

NPD tools: Any structured aids, managerial or technical in nature, used for structuring or influencing the management and effective execution of the NPD process and associated activities.

Purpose: Some research has been done outside New Zealand to investigate the impact of New Product Development (NPD) tool use on product innovation project outcomes, while very little has been done within New Zealand. It is still unclear which specific tools or categories of tools are most appropriate for supporting and enhancing the NPD process. The central theme of this research is to study the use of NPD tools in support of NPD projects in developing more successful products.

Conditions: The questionnaire is anonymous and you will not be identified as a participant. Provision of your email address is optional and will only be used for entering you into the petrol voucher draw, and for sending you a copy of the research findings. Upon receipt of your questionnaire your email address is separated from your responses. You can rest assured that the identifying password (token) is not kept with your responses. It is managed in a separate database, and will only be updated to indicate that you have (or haven't) completed this survey. There is no way of matching identification tokens with survey responses in this survey.

You may withdraw your participation, including withdrawal of any information you have provided, until your questionnaire has been added to the others collected. Because it is anonymous, it cannot be retrieved after that.

By completing the questionnaire it will be understood that you have consented to participate in the project, and that you consent to publication of the results of the project with the understanding that anonymity will be preserved.

Done

NPD Tool Survey

0% [ ] 100%

1. PRODUCT / PROJECT

What is the name of the product for which you are completing this survey (hereafter referred to as THE PRODUCT)?

[ ]

How would you categorise THE PRODUCT?

Choose one of the following answers

- ○ Consumer
- ○ Industrial
- ○ Defense
- ○ Other [ ]

How would you categorise the **development project** for THE PRODUCT?

Choose one of the following answers

- ○ Cost Reduction
- ○ Repositioning of current product
- ○ Incremental improvement to current product
- ○ Addition to existing lines
- ○ New to the Firm
- ○ New to the World (Breakthrough Product)

?

How many people in your SBU were involved in the project?

	1 to 5	6 to 10	11 to 20	21 to 30	31+
Size of team	○	○	○	○	○

? A Business Unit / Strategic Business Unit (SBU) is defined as a distinct business with distinct products and markets. If there is only one Business Unit in your firm, the business unit and firm level will be the same.

What was, or do you estimate to be, the length of time (in months) to develop THE PRODUCT from the initial idea to delivery to the first customer?

[ ]

Only numbers may be entered in this field

How many NPD projects has the core development team of the THE PRODUCT completed in the last three (3) years?
N/A = No Answer

	zero	1 to 2	3 to 5	6 to 10	more than 10	N/A
Radical Innovations (New to the World)	○	○	○	○	○	◉
More Innovative Projects (New to the Firm, Addition to or Major Revision of existing lines)	○	○	○	○	○	◉
Incremental Innovations (Cost reduction, Repositioning or Improvement of current product)	○	○	○	○	○	◉

<< Previous | Next >>

[Exit and Clear Survey]

Resume Later

NPD Tool Survey

0% 100%

2. STRATEGY AND PROCESS

Was the development of THE PRODUCT guided by a formal innovation strategy of your organisation?

○ Yes
○ No

Innovation Strategy: The firm's written positioning statement for developing new technologies and products.

Please check the box that most closely describes the product development process that was used for developing THE PRODUCT.
Choose one of the following answers

○ No standard approach to new product development
○ While no formally documented process was followed, we followed a clearly understood path of the tasks to be completed in product development
○ We followed a formally documented process where one function completed a set of tasks, then passed the results on to the next function, which completed another set of tasks
○ We followed a formally documented process where a cross-functional team completed a set of tasks, management reviewed the results and gave the go-ahead for the team to complete the next set of cross-functional tasks

How many **major development stages** does the product development process under question have?

Only numbers may be entered in this field

Enter "0" if no standard approach to NPD was followed

How many **major development stages** does the product development process under question have?

Only numbers may be entered in this field

Enter "0" if no standard approach to NPD was followed

During the development of THE PRODUCT, how much consideration was/is given to each of the following aspects?
N/A = Not Applicable

	1 Very little	2	3	4	5 Very much	N/A
Optimised product engineering & design	○	○	○	○	○	◉
Product strategically positioned	○	○	○	○	○	◉
Product aligned with customers' needs and requirements	○	○	○	○	○	◉
Financial feasibility	○	○	○	○	○	◉
General management and planning	○	○	○	○	○	◉
Manufacturability	○	○	○	○	○	◉
Creativity and problem solving	○	○	○	○	○	◉
Information sharing and management	○	○	○	○	○	◉
Risk management	○	○	○	○	○	◉
NPD team support	○	○	○	○	○	◉
Learning and review (for benefitting future projects)	○	○	○	○	○	◉
Decision making	○	○	○	○	○	◉

<< Previous | Next >>

[Exit and Clear Survey]

Resume Later

NPD Tool Survey

0% 100%

3. TOOL USE

A large number of tools and techniques are available for improving new product development. For each category of tools presented, please indicate **which tools your team have used** in developing THE PRODUCT.

The scale refers to the degree to which you used aspects of a particular tool.

N/A = Not Applicable (not used)

Product Design and Engineering Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Collaborative Product Development	○	○	○	○	○	◉
Computer Aided Design (CAD)	○	○	○	○	○	◉
Computer Aided Engineering (CAE)	○	○	○	○	○	◉
Design of Experiments (DOE)	○	○	○	○	○	◉
Design for X (DfX)	○	○	○	○	○	◉
Quality Function Deployment (QFD)	○	○	○	○	○	◉
Design Mock-up	○	○	○	○	○	◉
Alpha Prototype	○	○	○	○	○	◉
Beta Prototype	○	○	○	○	○	◉
Gamma Prototype	○	○	○	○	○	◉
Design for Six Sigma	○	○	○	○	○	◉
Value Analysis/Value Engineering (VA/VE)	○	○	○	○	○	◉
Rapid Prototyping	○	○	○	○	○	◉

? If necessary click on the tool to view a short description.

Product Strategy Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Portfolio Analysis	○	○	○	○	○	◉
PESTE Analysis	○	○	○	○	○	◉
Porters Five Forces	○	○	○	○	○	◉
Intellectual Property Protection	○	○	○	○	○	◉
Competitor Analysis	○	○	○	○	○	◉
Scenario Planning	○	○	○	○	○	◉

? **N/A = Not Applicable (not used)**

Market/Market Research Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Conjoint Analysis	○	○	○	○	○	◉
Discrete Choice	○	○	○	○	○	◉
Ethnography	○	○	○	○	○	◉
Voice-of-the-Customer (VOC)	○	○	○	○	○	◉
Diffusion Models	○	○	○	○	○	◉
Lead User	○	○	○	○	○	◉
Needs Analysis	○	○	○	○	○	◉
Concept Testing	○	○	○	○	○	◉
Beta-testing	○	○	○	○	○	◉
In-market Testing	○	○	○	○	○	◉
Limited Roll-out (Test Marketing)	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Project Finance Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Financial Analysis (ROI, IRR, NPV, DCF, Breakeven)	○	○	○	○	○	◉
Sales Forecast	○	○	○	○	○	◉
Cashflow Forecast	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

General Management & Planning Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Concept Statement	○	○	○	○	○	◉
Project Management	○	○	○	○	○	◉
Feasibility Study	○	○	○	○	○	◉
Business Case	○	○	○	○	○	◉
Marketing Plan	○	○	○	○	○	◉
Total Quality Management (TQM)	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Manufacturing Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Statistical Process Control / Control Charts	○	○	○	○	○	◉
Process Flow Diagram	○	○	○	○	○	◉
Computer Integrated Manufacturing (CIM)	○	○	○	○	○	◉
Computer Aided Manufacturing (CAM)	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Creativity and Problem Solving Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Brainstorming	○	○	○	○	○	◉
Delphi Method	○	○	○	○	○	◉
Focus Group	○	○	○	○	○	◉
Morphological Analysis	○	○	○	○	○	◉
Product Life Cycle	○	○	○	○	○	◉
Roadmapping	○	○	○	○	○	◉
Synectics	○	○	○	○	○	◉
TRIZ	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Information Management Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Engineering Document Management System	○	○	○	○	○	◉
Knowledge Management	○	○	○	○	○	◉
Project Intranet	○	○	○	○	○	◉
Change Control System	○	○	○	○	○	◉
Configuration Management System	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Risk Management Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Failure Mode Effects Analysis (FMEA)	○	○	○	○	○	◉
Fault Tree Analysis	○	○	○	○	○	◉
Market/Computer Prediction Models	○	○	○	○	○	◉
Risk Assessment Matrix	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Team Support Tools

	1 Not thorough	2	3	4	5 Very thorough	N/A
Cross-functional Team	○	○	○	○	○	◉
Tele/Video-conferencing	○	○	○	○	○	◉
Design Review Meetings	○	○	○	○	○	◉
Workflow	○	○	○	○	○	◉
Teambuilding	○	○	○	○	○	◉

? N/A = Not Applicable (not used)

Learning & Review Tools						
	1 Not thorough	2	3	4	5 Very thorough	N/A
Expert Systems	○	○	○	○	○	●
Benchmarking	○	○	○	○	○	●
Customer Satisfaction Tracking	○	○	○	○	○	●
Malcolm Baldridge Awards Framework	○	○	○	○	○	●
Post-Launch Review	○	○	○	○	○	●
Post-Project Review	○	○	○	○	○	●

? N/A = Not Applicable (not used)

Decision Support Tools						
	1 Not thorough	2	3	4	5 Very thorough	N/A
Stage-gates	○	○	○	○	○	●
Real Options Theory	○	○	○	○	○	●
Checklists	○	○	○	○	○	●
Decision Screens	○	○	○	○	○	●
Selection/Evaluation Criteria & Screening	○	○	○	○	○	●

? N/A = Not Applicable (not used)

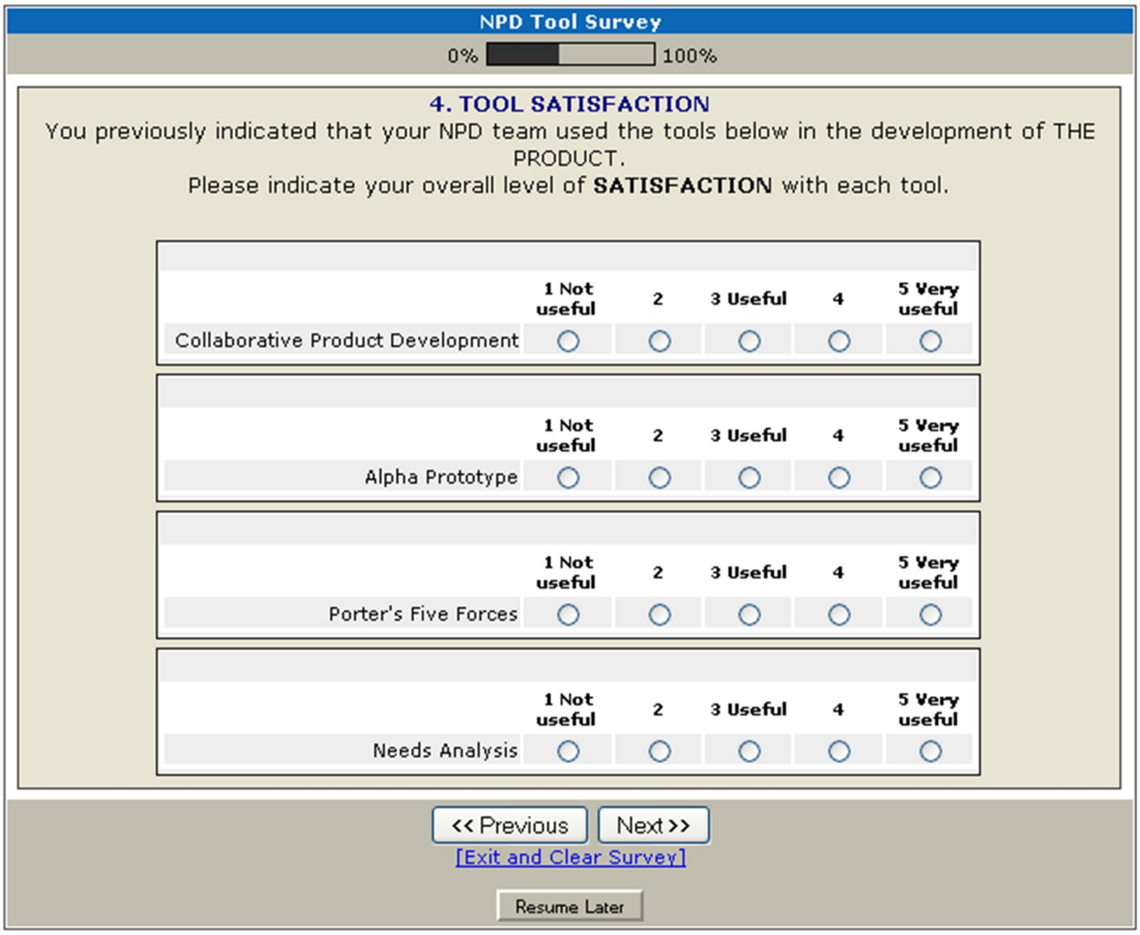
What other tools, not mentioned above, have you used or are you using in the development of THE PRODUCT?
Please also indicate how thoroughly you have used these other tools and how satisfied you are with them.

<< Previous | Next >>

[Exit and Clear Survey]

Resume Later

The tools shown in the 'TOOL SATISFACTION' section serve only as an example of tools that were selected in Section 3 of this survey.



NPD Tool Survey

0% 100%

4. TOOL SATISFACTION

You previously indicated that your NPD team used the tools below in the development of THE PRODUCT.

Please indicate your overall level of **SATISFACTION** with each tool.

	1 Not useful	2	3 Useful	4	5 Very useful
Collaborative Product Development	○	○	○	○	○

	1 Not useful	2	3 Useful	4	5 Very useful
Alpha Prototype	○	○	○	○	○

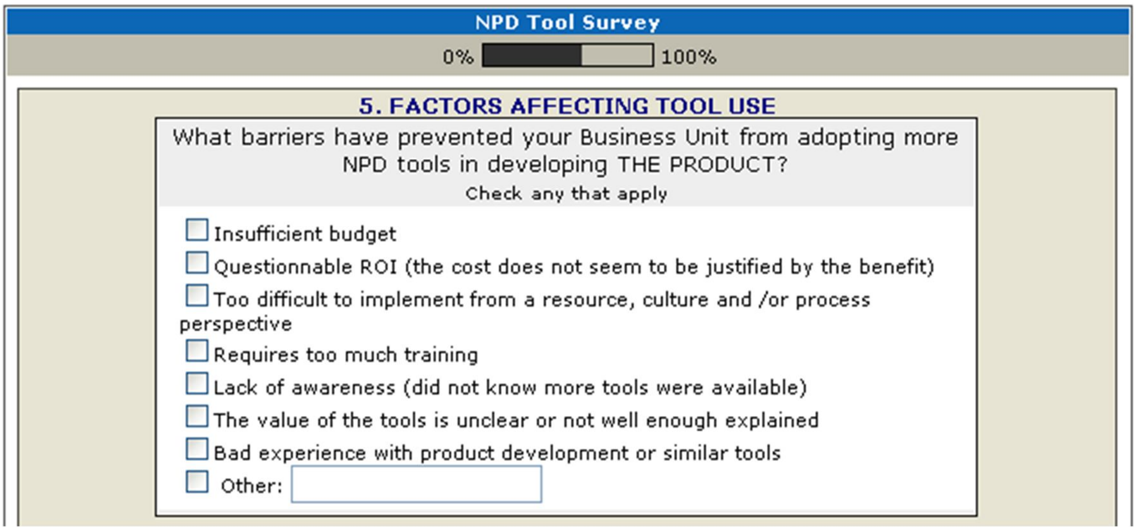
	1 Not useful	2	3 Useful	4	5 Very useful
Porter's Five Forces	○	○	○	○	○

	1 Not useful	2	3 Useful	4	5 Very useful
Needs Analysis	○	○	○	○	○

<< Previous Next >>

[Exit and Clear Survey]

Resume Later



NPD Tool Survey

0% 100%

5. FACTORS AFFECTING TOOL USE

What barriers have prevented your Business Unit from adopting more NPD tools in developing THE PRODUCT?

Check any that apply

- ☐ Insufficient budget
- ☐ Questionnable ROI (the cost does not seem to be justified by the benefit)
- ☐ Too difficult to implement from a resource, culture and /or process perspective
- ☐ Requires too much training
- ☐ Lack of awareness (did not know more tools were available)
- ☐ The value of the tools is unclear or not well enough explained
- ☐ Bad experience with product development or similar tools
- ☐ Other:

The following questions relate to NPD in general within your organisation.
Please indicate to what degree you agree with the following statements:

	1 Strongly disagree	2	3	4	5 Strongly agree	Not applicable
Top management is actively involved in the NPD process	○	○	○	○	○	○
NPD is an activity that involves all our departments	○	○	○	○	○	○
The level of communication among our departments is good	○	○	○	○	○	○
Our NPD strategy's focus is on turning out many new products	○	○	○	○	○	○
We have used NPD tools prior to this project	○	○	○	○	○	○

<< Previous Next >>

[Exit and Clear Survey]

Resume Later

NPD Tool Survey

0% 100%

6. PERFORMANCE

To the best of your knowledge, how well does this NPD project rate for each of the following performance measures?
N/A = Not Applicable (not important and not relevant)

	I don't know	1 Poor	2	3	4	5 Excellent	N/A
Speed to market	○	○	○	○	○	○	⦿
Launched on time	○	○	○	○	○	○	⦿
Adherence to budget	○	○	○	○	○	○	⦿
Degree of interfunctional cooperation	○	○	○	○	○	○	⦿
Degree of external collaboration	○	○	○	○	○	○	⦿
Met product performance specifications	○	○	○	○	○	○	⦿
Aesthetic design	○	○	○	○	○	○	⦿
Ergonomic design	○	○	○	○	○	○	⦿
Providing competitive advantage to firm	○	○	○	○	○	○	⦿
Met quality specifications	○	○	○	○	○	○	⦿
Serviceability	○	○	○	○	○	○	⦿
Customer acceptance	○	○	○	○	○	○	⦿
Customer satisfaction	○	○	○	○	○	○	⦿
Revenue goals	○	○	○	○	○	○	⦿
Profit goals	○	○	○	○	○	○	⦿

If you wish to make any comments with regard to the use of NPD tools, please do so in the space below.

NPD Tool Survey

0% 100%

7. ORGANISATION

What position do you hold in your organisation?

Choose one of the following answers

- ○ CEO/Director
- ○ Project Manager
- ○ Process Manager
- ○ Other

Please indicate the scope of your responsibilities for this project.

Check any that apply

- ☐ Technical / R&D
- ☐ Marketing
- ☐ Market research
- ☐ Financial
- ☐ Manufacturing
- ☐ Quality
- ☐ Other:

Please indicate your highest educational qualification.

Choose one of the following answers

- ○ School certificate
- ○ Certificate
- ○ Diploma
- ○ B Degree
- ○ Masters Degree
- ○ Doctorate
- ○ Other
- ◉ N/A

Please indicate your gender.

- ○ Female
- ○ Male
- ◉ N/A

?

How many full-time staff does your organisation employ?

Choose one of the following answers

- ○ 5 or less
- ○ 6 to 9
- ○ 10 to 19
- ○ 20 to 49
- ○ 50 to 99
- ○ 100+

How would you categorise your organisation?

Choose one of the following answers

- ○ Crown Research Institute
- ○ Technology Start-up in incubator
- ○ Technology Start-up
- ○ Manufacturing firm
- ○ Other

Please slect the industry category that best describes your business.

Choose one of the following answers

Please choose..

How long has your organisation been in existence?

Choose one of the following answers

- ○ Less than 1 year
- ○ 1 to 5 years
- ○ 6 to 10 years
- ○ More than 10 years
- ○ Don't know / prefer not to answer

Which of the following bands does your SBU's annual turnover fall into?

Choose one of the following answers

Please choose..

What percentage of your SBU's annual turnover come from exports?

Choose one of the following answers

- ○ 0%
- ○ 1-10%
- ○ 11 - 30%
- ○ 31 - 50%
- ○ more than 50%
- ○ Don't know / prefer not to answer

Please provide your work email address if you would like to receive an electronic copy of the research findings and if you would like to enter the draw for the twenty $50 petrol vouchers (optional).

? If you provide your email address, it will be separated from the rest of your responses to ensure anonymity.

If you would like to provide information for more than one NPD project, please request a separate password from gerrit.dewaal@pg.canterbury.ac.nz which will enable you to complete a second survey.
All survey entries will go into the draw for the twenty $50 petrol vouchers.

<< Previous | Submit

[Exit and Clear Survey]

Resume Later

Thank you for participating in the NPD Tool Survey

I really appreciate the time you took in completing it.

If you would like to provide information for more than one NPD project, please request a separate password from me which will enable you to complete a second survey.

All survey entries will go into the draw for twenty $50 vouchers.
The winners will be announced in an email message to all entrants.

If you have any questions about this survey, please contact Anton de Waal

at (03) 9407505

or gerrit.dewaal@pg.canterbury.ac.nz

Appendix 4: Project Questionnaire

Company Name: __________________________ **Date**: ____________________________

Project Leader: ___________________________ **Title**: ____________________________

Please answer the following questions for the product being studied, hereinafter referred to as The Product. The Project refers to the NPD project for which The Product was the outcome.

1. What is the name of The Product?

2. Provide a brief description of The Product.

3. How would you categorise The Product? □ Industrial □ Consumer

4. What is the predominant product architecture? □ Modular □ Integral

5. What was the starting date for The Project?

6. When was The Product officially launched?

7. Which aspects of The Product qualify it as radical (new-to-the-firm or new-to-the-world)?

8. Please indicate the total approximate development cost of The Project.

□ < $10,000 □ $10,000 to $19,000 □ $20,000 to $29,000 □ $30,000 to $39,000

□ $40,000 to $49,000 □ $50,000 to $59,000 □ $60,000 to $69,000

□ $70,000 to $79,000 □ $80,000 to $89,000 □ $90,000 to $99,000 □ > $100,000

9. Please name the primary market segments for The Product.

10. How many people formed part of the core project team?

11. Approximately how many people from within your organisation were involved in The Project? How many people from outside your organisation?

12. Where did the core technology of The Product originate from?

□ Own R&D □ In-licensing □ Other

13. Is The Product the first of its type that your firm developed? □ Yes □ No

If "No", how many new products has your firm developed prior to The Product?

14. Was The Product developed within its budgeted cost? □ Yes □ No

If "No", how much under or above budget? ____% below or _____% above budget

15. Did you complete The Project on schedule? □ Yes □ No

If "No", how many weeks ahead or behind schedule?

16. Which of the following performance measures were important to you? Tick all that apply.

□ Speed to market □ Launch on time □ Adherence to budget □ Achieve revenue targets □ Achieve profit targets □ Product serviceability

□ Plenty of inter-functional cooperation □ Significant external collaboration

□ Meet product performance specifications □ Meet quality specifications

□ Product provides competitive advantage to firm □ Product accepted by customers

□ Product satisfies customers □ Aesthetic design □ Ergonomic design

17. At this point in time, how successful do you perceive The Product to be?

□ A big failure □ A failure □ Moderately successful □ Successful □ Very Successful

18. Over its life cycle, how successful do you think The Product will be?

□ A big failure □ A failure □ Moderately successful □ Successful □ Very Successful

19. In hindsight, what aspects of The Project worked very well?

20. In hindsight, what aspects of The Project did not work so well?

21. What was/were your role(s) in The Project?

22. What is your highest qualification?

23. Briefly describe your NPD Experience.

24. Have you outsourced aspects of The Project? □ Yes □ No

If "Yes", please indicate what elements and to what types of organisations.

Element: __________________________ Type of organisation: ______________________

Element: __________________________ Type of organisation: ______________________

Element: ____________________________ Type of organisation: ________________________

Element: ____________________________ Type of organisation: ________________________

Element: ____________________________ Type of organisation: ________________________

25. Is The Product aimed at the domestic market? ☐ Yes ☐ No

26. Is The Product aimed at export Markets: ☐ Yes ☐ No.

If "Yes", have you achieved export sales yet? ☐ Yes ☐ No

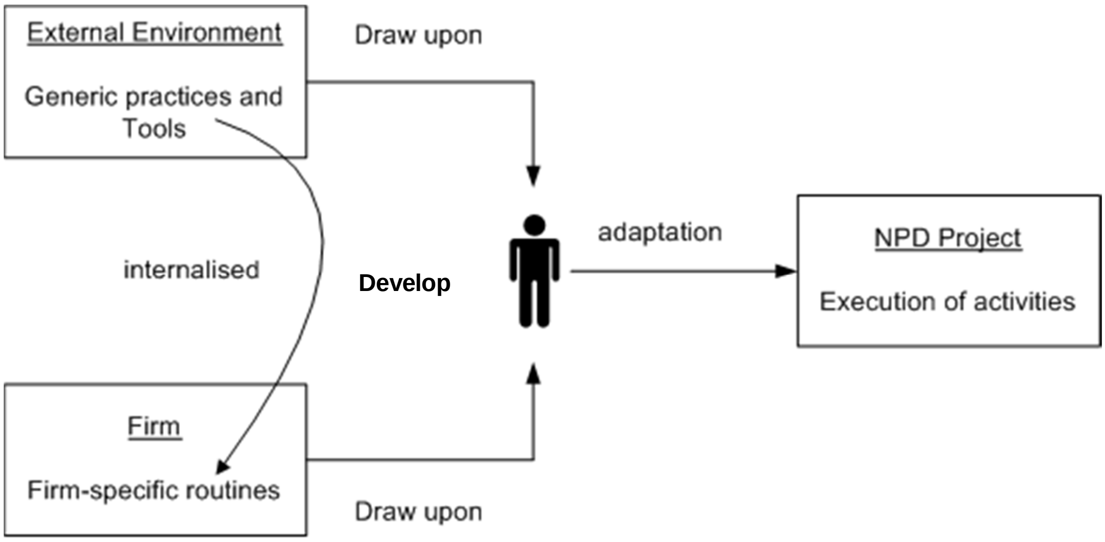
Appendix 5: Case Study Interview Questions

1) Please run me through the project and explain your involvement in it, in particular the role you played and the activities you carried out.

- How well did the stage-gate process work in guiding your development effort?
- How are tools linked to activities in your NPD process?
- When you use a tool, how strictly do you follow the “user instructions” for that tool?
- When using a tool, how important is it to you to use it to its full potential?
- What aspect/s of the job that needs to de done determine/s to what level of depth you will use a particular tool?

2) What were your **main reasons** for using tools? (**benefits**)
3) Considering the **categories** of tools in which your team scored low on tool adoption, would you recommend increased tool usage in any of these categories? Why or why not?
4) Do you think you have used an appropriate **amount of tools** in this project, or could you have made better use of tools? If your answer is the latter, what prevented you from using more tools?
5) When you completed the tool survey, did you look at the tool definitions?
6) **You indicated in Exhibit 1 that you used certain tools more thoroughly than others. What amount or depth of use did you refer to?** (How do you interpret “thoroughness”?) Why have you used some tools less thoroughly?
7) Have you used these tools with a high degree of **flexibility**, for example to solve problems beyond those they were actually designed for, or did you mostly use the tools **rigidly**, in a **focused** way, for the purpose they were designed for?
8) **Were there instances in this project where you made adaptations or improvements to a tool or tools? If yes, which ones?** Was this adaptation intentional or simply because of your interpretation of how this tool should be used? **In what way was the tool adapted/improved? Why was the improvement necessary?** Has this led to better meeting your needs? Explain the situation.
9) If a tool is **modified** during a particular project so it better suits the firm’s circumstances, do you normally **record** such changes so it can be used in forthcoming projects? Can you provide any examples?
10) Were there instances in this project where you or your team started using a tool, but abandoned it after not succeeding with it? If yes, which tools? What were the reasons why the tool implementation failed?
11) Broadly speaking, have you applied individual tools only at **specific stages** in the NPD process, or throughout the process independent of stage?

12) Consider the schematic drawing below depicting a model of tool adoption and use. To **what degree** are your firm's tools 'internalised' into firm-specific routines?



13) In **what form** are the 'internalised' tools available to individual users for use in a particular project? (e.g. an informal 'pool of tools'; a formal tool kit; linked to stages and activities in the NPD process; 'belonging' to individuals; 'floating around' somewhere in the system.)

14) During this project, were you mainly **inclined to draw** upon internalised tools, or from the generic set of tools existing outside the firm in an ad-hoc manner when needed; or a combination of both?

15) Generally speaking, **how are new tools adopted** into your firm? (e.g. by management prescription; individual users' requirements/requests, enforced by collaboration partners.)

16) Is it **difficult** to bring **new tools** into the system? Why/why not?

17) Were there any **organisational obstacles** or **circumstantial factors** that prevented you from adopting and using certain tools in this project?

18) How often are new tools brought into the system? Can you provide some examples?

19) How are individual team members **made aware** of existing and new tools? What is the general level of **tool awareness** among your team members?

20) Did you, at any stage of the project, shy away from using more complex tools or tools perceived as **difficult to use**? If yes, can you name such tools? What exactly were the problems with these tools?

21) Did you, at any stage of the project, shy away from using tools that are known to take a **long time to implement**? If yes, can you name such tools?

22) Considering the tools that were used in the project, generally speaking - how **useful** were they? How do you judge the usefulness of a tool?

23) Did you get **good or bad** results for the tools you used **substantially**? Please elaborate.

24) Did you get **good or bad** results for the tools you used **superficially**? Please elaborate.

25) Have you found some tools **easier to use and easier to learn** than others? Which tools in particular are difficult to learn and use?

26) In this project, have you encountered **specific problems** with certain tools? If yes, please provide examples and describe the problems.

Appendix 6: Practitioner Questionnaire

1. Please indicate, on a scale of 1 (very little) to 10 (very much), how significant a role NPD tools played in this project overall: 1 2 3 4 5 6 7 8 9 10 (circle one answer)
2. Which tool(s), if any, did you personally bring into the project?
3. a) Did you pro-actively look out for new tools to use in this project? □ Yes □ No
   b) Were any new tools introduced in this project? □ Yes □ No

   If Yes, please specify:
4. Could any team member decide to introduce and use a particular tool in a given situation, or did they first have to obtain approval?
5. Have you received specific tool training, formal or informal, on any of the tools you used?
6. How do you normally become aware of: -

   (a) tools that are already available in the firm?

   (b) tools not currently being used by your firm?
7. Have you, at any stage in the project, weighed up alternative tools before implementing one in a particular situation? □Yes □ No Please explain:
8. How did you know that the tools you used could potentially be helpful to you?
9. a) In this project, have you purposely considered the potential benefits and disadvantages of each tool prior to using it? □ Yes □ No
   b) Why or why not?

Thank you so much for your time!

Appendix 7: Letter of Invitation to Participate in Case Study Research

Case Study Research on New Product Development (NPD) Activity and Tools

I am a full-time lecturer in Innovation and Product Development at the Christchurch Polytechnic Institute of Technology and would like to invite you to be part of a research project: I am currently undertaking my PhD through the University of Canterbury, conducting case study research among companies in the Canterbury region on New Product Development (NPD) activity and tools. This specific part of the study forms part of a bigger project aimed at identifying how New Zealand businesses can make better use of NPD tools in developing successful products.

Preliminary screening has identified that your company meets the eligibility criteria for this study and I would therefore be delighted if you would agree to participate in this study. Even though my role will primarily focus on data collection in the first instance, I will endeavour to present the research findings in an advisory manner that will hopefully be of benefit to your company. I anticipate plenty of opportunity for further discussion on best practice issues between your NPD team members and myself.

The attached sheet provides detailed information regarding any participation in this study. I will contact you shortly to see if you are agreeable to participate in this project. Please note that I may be required to identify your company in my final thesis, but not in academic journal papers. A three-year embargo on the thesis will apply from the date of publication. I will strictly adhere to the practice of having participating companies approve all content before publication. If you have any questions or comments about this study, I would be happy to discuss them with you.

Sincerely,

Appendix 8: Tool Usage Intra-group Correlations of 20 Randomly Selected Tools

	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20
T01	1	1.000**	0.189	0.447	-0.135	-0.270	.736*	-1.000**	-0.316	0.866	-0.369	0.083	-0.522	-0.092	.a	0.299	-0.101	0.255	-0.556	0.406
T02		1	0.134	0.087	-0.045	-.424*	.880**	-0.250	-0.017	0.414	.674**	0.200	0.475	0.163	0.355	0.245	.411*	0.382	.571*	0.078
T03			1	0.521	0.192	0.508	0.443	0.327	0.000	-0.154	-0.274	-0.423	-0.168	0.221	-0.025	0.144	0.181	0.971	0.535	.845*
T04				1	0.342	0.122	0.212	.422*	.397**	.356*	.592**	.352*	.522**	.411**	0.265	.369*	.413**	-0.134	.336*	0.063
T05					1	0.246	0.559	0.592	.526*	0.057	0.408	.526*	0.438	0.179	0.539	0.175	.592*	.947*	0.087	.989**
T06						1	0.235	0.108	.631**	-0.151	-0.285	0.242	0.309	.223*	0.262	.451**	0.135	0.292	0.096	0.228
T07							1	0.155	.821**	.564*	.580*	.516*	.566*	0.114	0.433	0.169	0.124	0.240	0.476	0.091
T08								1	.435*	0.383	.494*	0.494	.578*	0.364	.606*	-0.020	.724**	0.214	.533*	0.119
T09									1	0.142	0.053	.379*	.691**	.440**	0.133	.505**	0.104	-0.081	0.331	0.240
T10										1	.407*	.688**	0.389	.379*	.611*	.667**	0.262	-0.376	0.374	-0.248
T11											1	0.342	0.472	0.255	.611**	0.239	.563**	-0.179	.558**	.481*
T12												1	.592**	.306*	0.173	.503**	.503**	0.012	.401*	.732**
T13													1	.417*	.585*	0.377	.633**	0.492	.773**	0.320
T14														1	.356*	.565**	.304*	-0.076	.407**	0.309
T15															1	0.165	0.214	.487*	.420*	-0.187
T16																1	.577**	-0.092	0.313	.543**
T17																	1	0.215	.485**	.591**
T18																		1	0.378	0.265
T19																			1	0.313
T20																				1

**p< 0.01 ; *p<0.05

Key: T01 - Computer Integrated Manufacturing; T02 - Project Intranet; T03 - Control Charts; T04 - Competitor Analysis; T05 - Tele/Video Conferencing; T06 - Design Mock-up; T07 - Computer Aided Manufacturing; T08 - Stage-gates; T09 - Beta Prototype; T10 - Benchmarking; T11 - Checklists; T12 - In-Market Testing; T13 - Product Life Cycle; T14 - Brainstorming; T15 - Knowledge Management; T16 - Limited Roll-out; T17 - Marketing Plan; T18 - Change Control System; T19 - Workflow; T20 - Voice-of-the-Customer